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GENERAL ELECTRIC Review

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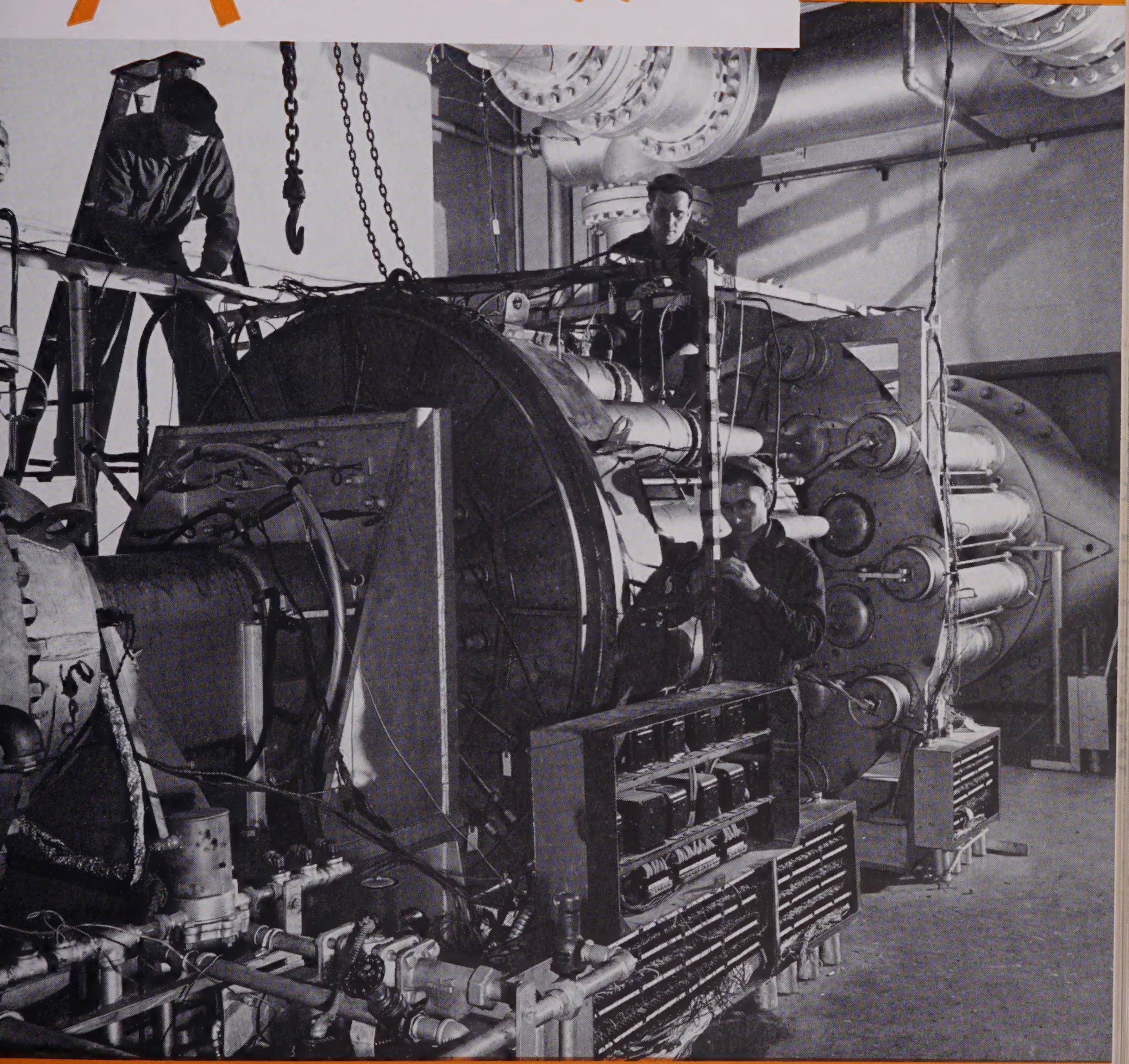

July, 1948

RADIO "TRAFFIC COP" with a good heart!

Operating where audio frequencies crowd the thoroughfares, variable attenuators assure precision volume control in speech input equipment for radio consoles, sound motion pictures, public address systems, and television.

With a "traffic cop" of this type in each microphone circuit of a multi-microphone set-up, input volume of one unit can be gradually faded out while that of another is increased; close-up and background program effects can be reproduced with whatever degree of contrast is desired; and the resultant mixing of all microphone inputs can be precisely and smoothly handled, through a master gain control, to meet all variations in program tonal intensity.

Since impedance of a circuit is kept constant while volume is changed, uniform performance is obtained without sacrifice of quality.

To assure topnotch results, the maker —Daven Company of Newark, N. J.— specifies that *all* its resistors, "standards in the industry", be wound with wire drawn from Driver-Harris electrical heat and corrosion-resisting alloys: Nichrome*V, Nichrome*, Advance*, D-H Manganin and the newly developed 331 Alloy which has very high specific resistance and a very low temperature coefficient of resistance.

If *you* require electrical resistance wire of outstanding uniformity, high stability, and long life, be guided by the example of Daven, whose products are used the world over, and have Driver-Harris supply your needs. For D-H alloys are the very heart of good electrical equipment of all kinds. Send us your specifications.

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Nichrome is Manufactured only by

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HARRISON, NEW JERSEY

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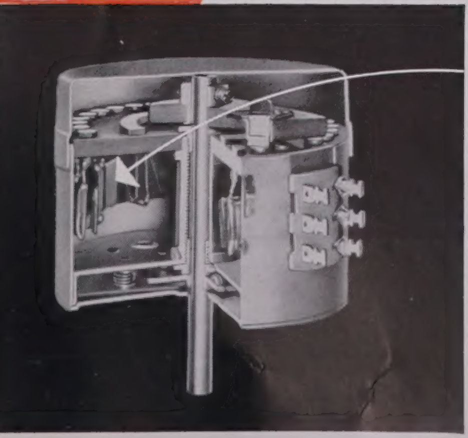
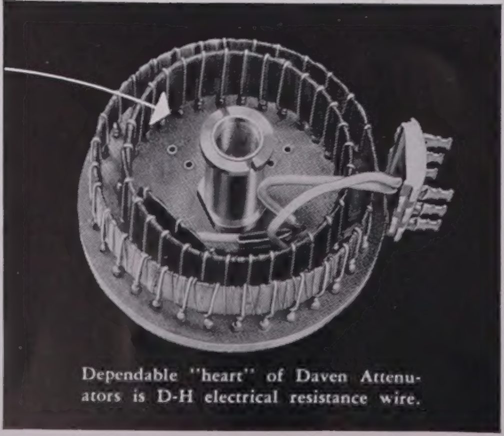
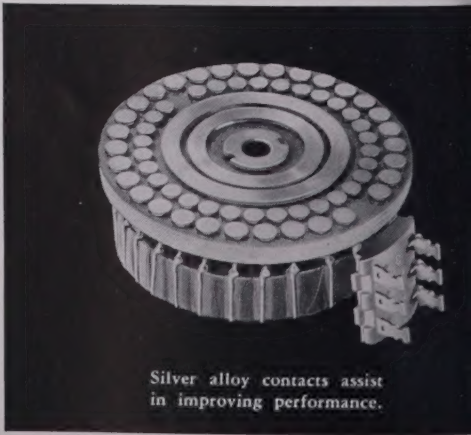




Dependable "heart" of Daven Attenuators is D-H electrical resistance wire.



Silver alloy contacts assist in improving performance.

Notably compact, Daven Rotary-type Variable Attenuators are made in sizes from 1¾" to 2¾" outside diameter. Standard units, giving up to 45 steps of attenuation, are available with built-in cueing control, enabling recordings, transcriptions, remote or network programs to be cued without necessity for auxiliary switching mechanism. Accuracy of resistance: from 0.1% up.

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GENERAL ELECTRIC Review

JULY, 1948
Vol. 51, No. 7

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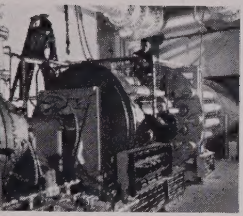

THE COVER

This is not an oversize jet engine although the
esemblance is striking. It is the structure for testing
as-turbine elements at the General Electric's new
ircraft gas-turbine laboratory at Lynn, Mass.,
here turbines having ratings as high as 30,000 hp
ill be tested. The laboratory and its equipment
ave been designed not only to simplify and speed
p the complicated job of jet testing, but to include
eans for simulating the operating conditions as-
ociated with altitudes up to 70,000 ft and tem-
eratures ranging from 90 F below zero to 160 F
bove. On p. 47 is illustrated another of the labora-
ory's major pieces of testing equipment.

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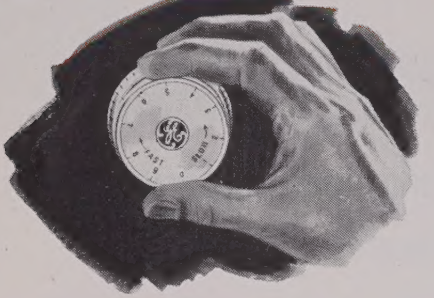
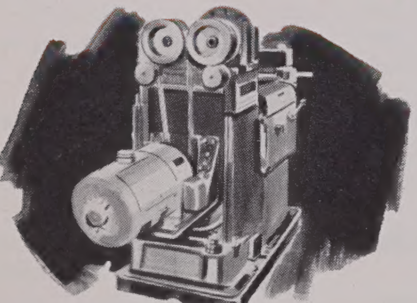
dial any speed . . .



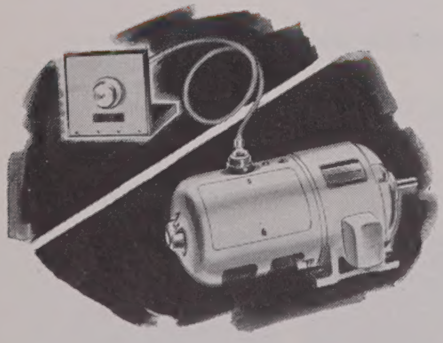
At the twist of a dial, the new Tri-Clad Type ACA induction motor will operate at any speed over a 3 to 1 range! What's more, it will do it while running on alternating current — without any converting equipment or mechanical devices whatsoever. It changes speed quickly and smoothly. In fact, wherever an adjustable-speed drive will improve quality or quantity of output, the Tri-Clad Type ACA induction motor is a simple, economical solution.

for any machine . . .



The list of applications to your right is only a glimpse at the hundreds of potential uses where this new Tri-Clad adjustable-speed motor might well be considered. Its simplicity and ease of installation make it an easy motor to fit to the job. Standardized NEMA dimensions are used so *there are no new mounting problems*. Its overall length is only slightly more than a constant-speed motor of comparable rating. And for the work it does, the Type ACA is one of the lightest motors in its field.

from any location!



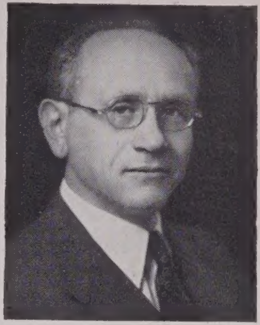
There are few limitations on your choice of location for this Tri-Clad motor, at the present offered in dripproof construction. Famous Tri-Clad construction gives it a sturdy frame for *extra protection* against physical damage; improved winding insulation for *extra protection* against electrical breakdown; and rigid bearing mountings with easy-to-lubricate bearings for *extra protection* against operating wear-and-tear. For remote control, a flexible cable or pilot motor is available. For more information, write today for Bulletin GEA-4883. *Apparatus Department, General Electric Company, Schenectady 5, N. Y.*

GENERAL ELECTRIC

The Twenty-first Steinmetz Memorial Lecture

POTENTIALITIES OF THE ELECTRICAL INDUSTRY IN SHAPING THE DESTINY OF AMERICA

By PHILIP SPORN
President, American Gas and Electric Company



Philip Sporn

AT THE outset it is pertinent to ask "What is the destiny of America?" The entire world, and more particularly the western world and our western civilization, is facing today a major crisis. The outcome of that crisis will determine, perhaps for centuries, whether the civilization will continue to new levels of progress and achievement, or, like earlier civilizations, will end in catastrophe and retrogression.

If America has a particular destiny to fulfill, it is to exert enough influence on history that our present civilization will not only continue but will ascend to new levels of progress and achievement. It can best do this by precept and example, by co-operation with other nations of like aims and objectives, and by giving help to those who need help. Above all, it will help bring this about by building within its own borders a society that is strong, brave, and confident of its future; a society in which human welfare will be raised to levels where want, hunger, and fear will disappear, and yet one in which all this will be done without demanding that the workers labor so arduously as to leave them no time, energy, or will for practicing and enjoying the spiritual and aesthetic activities of living.

The International Scene

Let us examine the nature of the crisis that is confronting western civilization. After a most brilliant but exhausting victory over Fascism and Naziism the western nations face a similarly victorious, and perhaps even more exhausted, totalitarianism—Russia and her satellites, our erstwhile allies. And each side is terrified by the growth in strength and influence of the other. Each distrusts the other, but perhaps for different reasons. And, if we can arrogate to ourselves the sole objectivity of judgment, we might add—with much more basis for distrust on our side than on the Russian. But in saying that we ought not to expect the Russians to agree with our view.

The scene is thus set for an explosive act to bring about war—an atomic war—with all the tragic horror that will follow in its train. And if, aghast at the black prospect that this opens up, we were to resolve to embark on a course of conduct that would with certainty avoid such a catastrophe, we would run into the other horn of the tragic dilemma—the conquest of the world by Communism.

That this danger is real and menacing has come to be recognized comparatively recently. Only a short while before the outbreak of World War II, when the threat, horror, and barbarism of Fascism were clearly discernible, many men of good will actually believed that the world could move into the plateau of permanent progress through either the pass of Communism or the pass of Democracy. Thus Casson, while fully alive to the sterility and destructiveness of Fascism—to the fact that it was a movement and a creed which was the direct opposite of the great civilizing experiments of the past, and that it had nothing to offer mankind for the future—still believed that Communism was like Democracy in the respect that each sought to bring about a world in which progress is possible. True, there would be some differences: Democracy would unite mankind according to mankind's own wishes, permitting each separate region to live as it wills, while Communism would unite mankind on a basis of uniformity—perhaps forcible uniformity. But each offered, according to Casson, the fundamental unifying force for the existence and development of a human civilization. During the war, when our great need for allies in the struggle against Fascist barbarism naturally blinded us to some of the glaring divergences between fact and its idealization, many others, normally more discerning, adopted the same view.

Divergent Paths of Democracy and Communism

Actually, as is evident today, Democracy and Communism are too far apart to offer joint or parallel paths to the road of progress. The apparent ability of Communism to unite mankind is bound to end in failure because of the inherently divisive nature of Communistic doctrine and dogma inherited from the almost mystically revered Communist Manifesto. The notions that as the use of machinery is developed the burden of labor will be increased; that the petty bourgeoisie will be swallowed up in the proletariat; that the worker has become a pauper and that pauperism is increasing even

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—Ed.

more rapidly than population and wealth—these doctrines have been clearly disproved in the most highly developed capitalist countries. They are, however, today's unchanged Communist doctrine. They are untrue; that, however, does not prevent their being used today—a hundred years after their first formulation—as a corrosive agent to undermine the supporting structures of anciently established national groups in order to advance the boundaries of the world's area controlled from today's center of communistic faith and dogma. But the vitriolic intolerance for dissidence of opinion, the fanning of the flames of class antagonism, the suppression of basic freedoms—these cannot in the long run offer a cementing force of sufficient permanency to develop the unit of mankind which is so necessary a condition for progress.

Yet it must be admitted that, in seizing upon and underlining the fact of class antagonism, Communism at its birth grasped at a truth. The antagonism between master and slave of Roman times carried over into the era when the organization of society was on a master-and-servant basis. It did not disappear when the servant disappeared and there emerged the industrial worker. The doctrine that as industrialization develops the worker becomes pauperized has proved to be fallacious. On the contrary, the record is clear that as technology has developed the minimum standard of living has risen to heights unimagined only a generation or two previously. This should have eliminated entirely the evil of class antagonism. That it hasn't done so at all in many countries, and hasn't disappeared entirely—even in this country—is proof of the virility of this antagonistic feeling and of the need for continuing the battle to unify mankind.

Well-being and Social Justice

If Democracy is to grow and flourish and bring forth the fruit of human co-operation requisite to a unified civilization, it must be rooted in economic well-being and social justice. And the latter is of no avail if the former is at bare subsistence level. If Democracy is to triumph, if free man is to reach out for the stars, our economic system must travel along the path of increasing productivity and increasing well-being of the individual—that is, of greater availability to the average man of the products of earth and hand and machine. While that is being accomplished, it is imperative that to the fullest extent possible it be accompanied by lessening the burden and toil of the individual, or at least by the elimination of that part of the individual's job in which he is used merely as an energy producer. With it there must also be recognition of the depth of the human demand—the almost instinctive and passionate urge—for social justice. It will be necessary therefore to be on the alert for injustices and for inequalities that have no social-economic basis, and necessary also to eliminate them or to mitigate their effect. But that phase can be dealt with as we elevate the level of well-being of the social unit as a whole, by increasing its productivity.

What is the destiny of America? Its destiny was cast at Valley Forge, wrought at Gettysburg, and tempered in the blood of its sons who successfully fought rising tyrannies in two World Wars. Under a system guaranteeing life, liberty, and the pursuit of happiness, its citizens have developed their agriculture, industry and commerce, and their level of physical welfare to the highest point reached on the face of the earth. This is the torch which America has held up before the world as a flaming beacon. It is in the preservation of these ideals of human freedom and welfare in this country, and in their expansion throughout the world, that America will fulfill her destiny.

Challenge to the Electrical Industry

It is here that the great opportunity for the electrical industry lies—in extending and developing our industrial system by the use of more extensive, more skillful, and more intensive applications of electrically powered machines and tools to increase productivity and to make more of the products of these machines and tools available to man; in bringing about more intensive and more intelligent cultivation of the soil to increase its fruits and products while reducing the effort and labor exerted, and so make available more food, without which man will perish, while raising the condition of living of those engaged in farming so as to bring the spiritual products of our civilization within their reach; in improving living in the home so as to make the home a more comfortable, a more relaxing, and a more spiritual environment for all the members of the family; and finally, in making the nation strong so that, confident in its strength but guided by modestyand justice, it can co-operate with other nations, help them to live, but be also assured of its own ability to live and survive.

It is in these four fields—industry, farm, home, and nation—that the electrical industry—the machine, tool, and appliance builders, and the manufacturers and suppliers of electrical energy—has an opportunity to play a vital part in shaping the destiny of America and thus of the whole western world. A large part of the world is looking toward America to show the way; it is hoping and praying for America to succeed, and it would view as its own major tragedy America's failure to succeed.

Let us review briefly America's contribution to the world's industrial and farm economy, appraise the accomplishment of the electrical industry, and from that try to chart the course of opportunity open to the electrical industry. With approximately one-fifteenth of the world's population, about the same proportion of its land area, and little more of the world's natural resources, the United States today produces one-third of the world's annual output of goods and services. No less an authority on waging war than Stalin is author of the statement that it was American war production that tipped the balance against, and insured the defeat of, the Axis nations. This, however, was no sudden miracle. The productive achievements of 1944 were the culmination of a century of progress and growth in industrial production.

ur Production Record

Between 1850 and 1944 our population increased bout six times, our labor force a little more than eight mes, and our total labor output about five and one-alf times; but the net output of American industry as about 29 times as large in 1944 as in 1850. Thus ne productivity of human labor, or the output per anhour for the economy as a whole, showed a fivefold icrease during the period of less than a hundred years nding in 1944. The study made by Snyder of national icome and wage and salary payments through this ame period has clearly shown that there exists a close nd almost unchanged relation between national inome—that is, the well-being of all the population—nd the wage and salary payments of people in industry.

Because of the limited ability of the human body to roduce useful work, the progress in output per manour is almost directly related to the increasing use of ower-driven tools and equipment. Orginally these ere almost all mechanically driven tools, but more nd more have become electrical until, today, the elecrical portion constitutes almost 93 per cent of the otal. It is interesting to examine the figures on the mount of power that has backed up the American orker during the past century. Here are recent data:

1849	Very little
1879	1.3 hp
1909	2.9 hp
1929	4.86 hp
1939	6.4 hp
1947	7.2 hp

These figures, indicating more than a fivefold increase the period 1879-1947, leave no room for doubt that merican productivity and individual well-being are losely related to the lavish use of tools and equipment nd the energy needed to drive these tools. If more is be produced per unit of human labor, more tools and ore energy to drive them will have to be employed; nd that means electrically driven tools and electrical nergy.

urther Applications for Tools and Power

In our competitive system are there opportunities r further application of tools and power that would e sound from an economic point of view? An examinaon of the entire field of industry shows amazing pportunities and potential applications of vast proortions. Not only will electrical applications be reuired in the normal expansion of industry, due to opulation growth and the expanding of all existing ndustry to take care of this additional population, but pecial and new applications in such industry, and any heavy-energy-using new industries will further dd to the total. Thus in each of such relatively new pplications as radio-frequency heating, electric furace brazing, infrared heating, and continuous annealng of metal products, annual increases in demands arying from 10,000 kw to 200,000 kw can be expected the next ten years. In the same period such established processes or industries—all of them heavy energy consumers—as welding, electric-arc furnaces, resistance furnaces, reduction of aluminum, and reduction of magnesium can be expected to call for an annual increase in power demand of 40,000 kw to 500,000 kw. Whether some of these demands can best, and therefore will, be supplied by the industries originating them is not too material; the electrical opportunity will be there in any case.

Besides those there will be increased demands in coal mining, ore beneficiation, fertilizing, and similar industries that will each require, or may require, perhaps an average of 100,000 kw per year over the next decade. The load represented by the sum of all these discloses an opportunity for the electrical industry over the next ten years which when measured by electrical demand totals an annual increase of between 1,500,000 and 2,000,000 kw.

In the study of the history of past civilizations and of man's progress and retrogression, the part played therein by the condition of his food supply must not be overlooked. It has, as a matter of fact, had superimposed on top of its cyclic variations a consistent, continuing, and vital trend—the race between population and food supply. In the United States this race has not been so noticeable heretofore because of the fortunate condition thus far in the ratio between population and arable land. But in other large sections of the world there is already an imbalance between population and the soil available to support it.

At the present time the United States is exporting large quantities of food. These have played, and are bound to play for some time to come, a major role in repairing the havoc wrought by the last war and in helping build up large segments of the western European population to positions where they can be substantially self-sustaining. If our country is to continue to be able to do this in the face of our own rapidly increasing population, it will be necessary to increase its agricultural output. To do that, presents a particularly difficult problem.

In the quarter century ending with 1945, while the population of this country increased from 106,500,000 to 139,600,000, an increase of approximately 31 per cent, the farm population declined from 31,600,000 to 23,600,000, a decrease of 25 per cent. In the same period the percentage of the farm population in relation to the country as a whole declined from approximately 30 to 17 per cent. This trend has temporarily been arrested. But it is evident that here in the United States, as in other countries, if more food is to be produced there must be more output per man employed and therefore more tools. Also, other factors will have to be changed without question: more and better fertilizers will be needed; more intensive farming will have to be practiced; higher yield and improved crops (like hybrid corn) will have to be resorted to. But there will always be the problem of increasing the output of farm commodities per man or per manhour, and here again the electrical industry will have to play a vital part.

Electric Power on the Farm

Admittedly farm mechanization is not as dependent upon electric power as is industry in general, because of the economic position that the internal-combustion engine holds on the farm. It is only when we analyze the multitude of chores that have to be performed, and the effect that their efficient performance has on the acreage that can economically be integrated into the single-family farm unit, that the importance of electric tools and electric energy on the farm is seen in clear perspective. What are the electrical opportunities here?

In the face of the remarkable progress made in bringing about the first step in rural electrification in the past decade, it is evident that mere electrification is not the avenue of approach. With a record of some 3,817,000 farms electrified by the end of 1947, another 460,000 expected to be electrified in 1948, and still another 750,000 reached by existing lines but not yet taking service, a bare 500,000 to 600,000 farms will remain to be reached in subsequent years. The job of initial electrification of the country's farms is, in other words, 90 per cent completed.

It is in farm-utilization figures that the story of opportunity is told. The record of these figures over the past 20 years is significant. They are:

1926....2339 kw-hr per farm customer per year
1931....2688 kw-hr per farm customer per year
1936....2050 kw-hr per farm customer per year
1941....1574 kw-hr per farm customer per year
1946....2182 kw-hr per farm customer per year

It is not too difficult to account for the decline in utilization in the fifteen-year period 1931-1946 when it is realized that in the same period there occurred a trebling in the farms electrified. It is more difficult to become reconciled to the average annual use for 1946 in the face of the corresponding figure of over 1300 kw-hr for the average residential home. What is the explanation? A number of reasons occur: the only relatively recent general availability of electric power on the farm; the backwardness of electroagricultural engineering, and the intervention of the war.

But now there is every reason to look forward to development of special electrical tools and services in every branch of farm activity: in the home, to perform most of the operations electrified in the city home; in crop processing, to carry out drying, baling, cropping, grinding, crushing, husking, vining, conveying, and many other related operations; in dairying, to milk, wash, boil, sterilize, pasteurize, cool, freeze, churn, separate, agitate, pump, ventilate—the list is almost endless and it extends into the other branches of farm activity. The opportunities open here are so large that there should be no real problem in doubling the average farm utilization in ten years and doubling it again in another ten. When we have reached that point, the annual kw-hr required by our agriculture will be approximately 45,000,000,000 kw-hr. This is over 20 per cent of the total energy furnished to every type of consumer by the power systems of the United States in 1947.

Stabilizing the Farm Industry

The gain to be achieved by grasping the opportunity to extend electrical applications on the farm goes beyond merely more production per manhour and more intensive cultivation of the land. It goes to the heart of stabilizing and assuring farming as a part of a balanced social-economic scheme in a democracy. The only certainty of steering clear between the Scylla of a peasantry and the Charybdis of a communized agriculture—either of which would be disastrous to democracy—is to encourage the maximum development of farm population as a sturdy, productive unit of the social-economic structure and as a fully integrated and indispensable part of our society.

The fact that more extensive and intensive electrification of work and living on the farm will be brought about will not only make farming a more productive enterprise, but will lessen human toil and labor. This will mean that the farmer and his family will be able to increase to a much higher level than today's their opportunity for leisure and can utilize this greater opportunity to participate in and to enjoy activities of a broad communal interest, of recreation, self-improvement, and aesthetic enjoyment. Thus the barriers between city and country will be removed and a social cleavage so common in many European societies avoided.

More Electric Services in the Home

The family is our basic social unit, and its habitat is the home. Here not only are congregated for the largest percentage of their total time the group constituting the unit whose members are held to one another by the strongest of human ties, but here also are developed the attitudes of its members toward society and the social-economic system which most often are capable of only minor mutations in later years. Here, rest and relaxation and surcease from toil are found by every member of the family no matter what his place in the social system—worker, professional man, or business man. But rest and relaxation are not promoted by conditions in the home calling for the efforts and exertions by numerous members of the family to carry out operations and perform functions that are basically chores or that call primarily for energy exertion. Nor is a physically uncomfortable home especially conducive to spiritual harmony. Yet we find that although practically every home in the United States has been electrified and almost no homes are being built today without electric service, the utilization of electric energy in the home is still amazingly low.

A series of figures on average annual consumption in the domestic homes of the United States over the past two decades is of interest in this connection:

1927.....450 kw-hr per residential customer per year
1932.....600 kw-hr per residential customer per year
1937.....805 kw-hr per residential customer per year
1942....1022 kw-hr per residential customer per year
1947....1438 kw-hr per residential customer per year

t is true that this more than trebling of annual conumption in 20 years represents progress in utilization f electrical devices in the home, but the progress has een slow and a great deal more needs to be done to ccelerate the rate of progress. Essentially this gets own to the development of the proper tools and ppliances and making them available for the average ome. Instead of the average home's having nothing nore in the way of appliances than a radio, an electric ron, one-fifth of an electric range, one-fifteenth of a ater heater, and a toaster, it should have the service nd comfort of the home laundry and the water heater, he electric range, the multitude of comfort-giving ppliances such as blankets, fans, space heaters, vacuum leaners, and myriads of others; and, with the develop-nent of television, very definitely the stimulation and njoyment that is bound to come from that art. If all hat is done, there is no reason why the average tilization cannot come up within a decade from the 947 figure of 1438 kw-hr to 2600 kw-hr, and by 1967 o a figure of 4800 kw-hr per year.

leating and Cooling Homes Electrically

The foregoing figures of growth of electric service tilization in the home are based on the heating and ooling of the home remaining in status quo. But why hould heating and cooling remain in status quo? Is here any other operation in the average home, outside f possibly the preparation of food, that is more imortant than heating and cooling? Is there any reason hy electricity, which admittedly is the cleanest, the nost readily available, and the safest form of energy, hould not be used for performing that most important ngle utility function if it can be done economically? he answer to both questions is No. But unfortunately he heat pump is not yet ready to be offered for use in he average home.

Progress in its development is being made. Thus, y the end of this year we hope to have at least ten eat-pump installations, of designs that give excellent romise of being successful, installed in typical resiential homes. But this has taken too long and the rate f progress needs to be accelerated. If you keep in mind, owever, that the heat-pump installation in an average ome will require not less than 10,000 kw-hr per year, nd if you assume that ultimately 10,000,000 homes will e equipped with heat pumps, you get an increased omestic consumption of 100,000,000,000 kw-hr per ear on that account alone. Suppose it can be brought bout within the next 20 years. What a magnificent pportunity that is when you consider the fact that the resent—that is, the 1947—total energy generation in he United States for all purposes was only 255,000,00,000 kw-hr!

There is another important phase of the heat pump: hat is the effect its extensive use would have on our upply of natural resources, not only on fuel but on a umber of our other basic resources. But I should like o defer this and treat it later as part of the consideration of opportunities open to the electrical industry in the field of national defense.

Electric Power's Contribution to National Security

I come now to the fourth avenue of opportunity, that of national defense and national security. During the recent war, and particularly at the peak of the war, we outproduced the Axis nations in combat munitions by more than 50 per cent, and we alone accounted for nearly 45 per cent of the armament output of all belligerent nations. Yet we did this with only about half of our productive power devoted to governmental requirements; and the remaining half was adequate to maintain a civilian standard of living equal to almost the highest prewar level ever achieved. In a large measure, we achieved this because of the high degree of mechanization and the large amount of power and number of power-driven tools that were available to back up the American worker, a figure that during the war was of the order of 7 hp per worker. The power to run that 7 hp, in turn, was available because of the magnificent job that was done during the war by the electrical industry, aided by the margins in capacity above loads with which the power systems entered the war period.

We have just started, and we will shortly be engaged in, a program of again building up the defenses and the armament of the country. To take care of those new developments that will be brought forth in connection with this armament program, and to be ready for such contingencies as may develop, it will be necessary to have an adequate supply of power, with margins more generous than those that are now available. And this is again an opportunity for the electrical industry.

Need for Balanced Utilization of Raw Materials

It is almost trite to say so—but it is true nevertheless—that no modern industrial nation is any stronger than its supply of raw materials to run and operate its industry. In discussing the industrial opportunities open to the electrical industry, I mentioned ore beneficiation and the electrical requirements that this will bring about. Our reserves of high-grade iron ore, particularly in the Mesabi region, are rapidly approaching exhaustion and will be only an item of history in the not too distant future. We will thus, as long as steel continues to play the part that it does today in the whole industrial structure, have to rely more and more on low-grade ores.

Both from an economic standpoint and in order to conserve for extraordinary conditions as much of the high-grade ores as is still possible at the present time, it is highly important to strike a better balance in their application than has been struck heretofore between steel and the lighter metals, specifically aluminum and magnesium. The development of these metals, in turn, offers an opportunity for the electrical industry to make a major contribution to national defense.

Again, our economical reserves of copper are today depleted so that only perhaps 25 years' requirements are left. We had to import copper to carry us through the late war. Our electrical industry is based upon copper and would today come to a standstill without it. And the electrical industry, through its machines and the electrical energy that operates them, furnishes the bone, the muscle, and the life-blood for most other industries in the country. If we are to extend the life of our present reserves, it is again necessary to introduce as quickly as possible the use of other metals, particularly aluminum, in order to have copper available for those applications where we have as yet found no substitute for copper. That transition is going on at the present time, but an acceleration of the process is needed; its realization will be another addition to the national defense.

Need to Conserve Fuel Resources

The importance of fuel in the national economy isn't half enough appreciated even by intelligent lay people, nor has the abundant supply of all fuels—coal, oil, and gas—been given enough credit for the industrial pre-eminence and the high level of economic welfare of the United States. Yet our proved reserves of petroleum, while standing close to an all-time high, may within a decade or so reach the scarcity basis. Our wanton use of nature's rich gift of natural gas may have been somewhat abated, but many of our fields are now exhausted; and we still use, by and large, the least valuable portion, the thermal part, of a complex and valuable chemical item.

In our coal fields nature has been particularly lavish and kind. Yet we have exhausted many of the best deposits. Until a short while ago, it was common opinion that our reserves were ample for 2000 to 3000 years' use. This is not a limitless supply, but it seemed to be one sufficiently large that we could appear almost indifferent to the efficiency with which coal was being utilized. That certainly is not the situation today. The time for complacency has definitely disappeared, and in its stead it is necessary to take a more sharply appraising look as to how best to utilize the more modest reserves that we probably possess.

Crichton, in a recent survey, has indicated his judgment that the total coal reserves available in the United States are only sufficient, at present rates of production and rates of mining, for the next 250 years, and that in the highly industrialized East where 92 per cent of the coal is produced and used, we have only 90 years' supply. It is obvious that more study of this question is justified; but if the actual conditions are anywhere nearly as critical as indicated by these figures, then here is one of the very great opportunities available to the electrical industry. It is a three-pronged fork: first, to improve methods of mining and rates of recovery of existing resources by better machines, tools, and processes—and in all of them electric power will play a most vital part; second, to improve prime movers and the efficiency of conversion of the fuel to electric energy; and finally, to improve the utilization devices, so that the same work or function will be performed at an expenditure of less energy and therefore less fuel.

Potentialities of the Heat Pump

It is most significant that in this connection the hea pump; and its development, has within it the seed o two large social-economic and long-term gains, botl bearing on conservation and, therefore, on strengthening national defense. First, a coefficient of performanc of 4.0 means a striking increase in the life of all available fuel resources. In fuel-burning electric-energ generating plants, over-all thermal efficiencies o approximately 40 per cent are within sight. If electri energy generated at that efficiency were used to hea our homes, commercial establishments, and office through the agency of heat pumps having a coefficien of performance of 4.0, the net result would be deliver to the heating coils of 160 per cent of the energy originally resident in the fuel. Thus at one stroke the potentia life of our present fuel resources, certainly of tha portion devoted to home heating, would be greatl extended—perhaps to a figure double what woul otherwise prevail.

Second, if the heating of homes by electricity i assumed to be an inevitable development, it is important to note that the heat pump, with its coefficien of performance of 4.0, would reduce to one quarter th copper otherwise needed for the transmission an distribution of the power devoted to that purpose The limiting of fuel burning to efficient, centralize plants, the further harnessing of the power in river and streams, the development of the potentialities o wind power and of nuclear fission in the future are al corroborative of this outlook on the future of electri heating and the contribution to the conservation o our copper and aluminum resources which this wil bring with it.

A Healthy Society Promotes National Defense

Finally, national defense will be strengthened perhaps to a greater degree than by any other singl contribution, by developing a strong, a healthy societ —a society that is highly productive, that has the foo necessary to sustain it supplied by a well-integrate farming population, and where the home continues t be the center of living activity; in short, a society tha is healthy and happy and that lives in harmony wit itself and with the world at large. Such a society wil be strong and will be able to defend itself. In makin its contribution to help bring about such a society, th electrical industry can make the greatest contributio to national defense.

How well is the electrical industry set up to gras this golden opportunity to help shape the destiny o America? Is all well? Is the probability of the no wide-open opportunity being seized and develope strong enough that we can count on it as an almos certain eventuality, or is there need for further preparatory work?

A careful examination of the problems involved leads o the clear conclusion that things are far from well, nd that it would be folly to proceed on the assumption hat the process of exploiting the opportunities open to he industry will be an automatic affair. There are too nany things still to be done, too many attitudes to be hanged, too many shoals to be navigated, before we an be sure of safely reaching the much desired shore.

We have, for example, a great deal of research ahead f us. If the opportunities so manifestly open to the lectrical industry are to be exploited, it will be ecessary to fill in some of the wide gaps in our science nd in our technology. We can do this if we carry on he necessary research, and some of it is going on. But the fuel problem, for example, is to become more ritical, then the reasons for more intensive work on ew and improved thermal cycles and for higher emperatures in power generation by steam become nore urgently persuasive. Higher levels of energy tilization will require, if they do not already do so, igher transmission voltages to transmit the larger locks of power from generation to load centers and o furnish greater capacity interconnection facilities etween generation centers and between adjacent ystems. The increased loads in the service areas will, economy in distribution is to be maintained, require ew ideas, methods, and techniques in distribution.

More extensive utilization of energy on the farms nd in our homes calls sharp attention to the need for nore research and development work on many farm evices and on home appliances to produce them at ower and lower costs to make possible more wide pread distribution. There is an urgent need to concenrate major effort on the development of the heat pump.

Again, it is necessary that we change our entire ttitude toward fuels: their general availability, the vailability of different classes for the tasks they have een traditionally performing, the possibility of dislacing some of them with fuels of lower quality, and he fullest economic exploitation of all of them. For xample, I doubt whether many people in the electrical ndustry—or the coal industry, for that matter—have iven much thought to the very important fact that the dditional steam-turbine-driven generating capacity nder construction and to be constructed in the fourear interval of 1948-1951 will, even after allowing for much greater margin of reserve in 1951, still require t the end of that year approximately 24,000,000 more ons of coal than were burned in 1947 for power eneration. The satisfactory working out of the fuel roblem, and of the problems arising from the fuel roblem, will take a great deal of pioneering, patience, evelopment work, and teaching.

pportunities and Obstacles in Shaping our Destiny

The very magnitude of the opportunity for shaping he destiny of the country, open to the electrical ndustry and lying ahead, carries the seed of its own rustration and of the throttling of its development. 'or it now appears fairly certain that by 1952 the electrical development of the country will result in a power demand of 66,000,000 kw. Now, while it is necessary to have generating capacity to meet such a demand, the demand itself can come about only if the tools, devices, and appliances are developed, installed and utilized to bring about the demand.

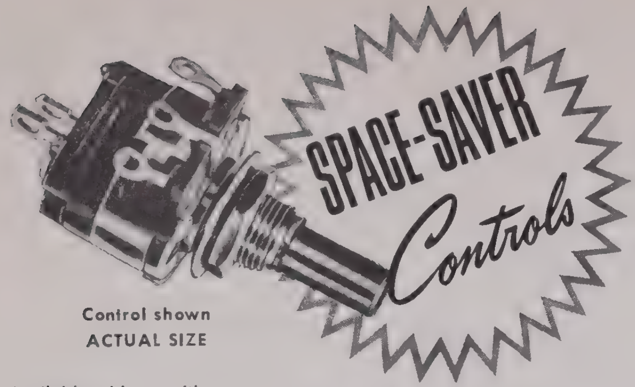
A projection of the presently known curve of growth of the power industry—on a much moderated basis, but taking into account the fruition of the opportunities for extending electrification in the many fields I have discussed—indicates a demand for 1957 of 86,700,000 kw and two years later a demand of 96,800,000, practically double the 1947 figure. The danger here, then, is that failure to believe such growth will take place will result in failure to make and to execute the necessary plans requisite to its consummation; this, in itself, will stifle the growth.

If growth takes place in spite of lack of preparation or lack of complete preparation up to the maximum possible under such adverse conditions, there is still the danger that it will be a halting and uncertain growth and that it will therefore contribute only a part of its full potential to the social-economic welfare of the country.

Another danger—perhaps only slight now, yet one not to be overlooked—is the prospect of more direct and extensive incursions by governmental agencies into the electrical industry. The industry has reached its present phenomenal development as the result of private invention, initiative, daring, and enterprise. The still-limited participation by governmental bodies in the field have had so far no materially sterilizing effect on progress and invention in the industry as a whole, but it is hard to visualize how such sterilizing and retarding effects would be kept out if more extensive inroads by government agencies were to take place.

Despite all obstacles that may prevent it, I have great confidence that the problems confronting the electrical industry in its exploitation of the opportunities open to it will be solved. Our industrial system, now the envy of the world as a mechanism for producing goods and services for the use of man, will be stimulated to greater achievement—to greater production, with lessened toil by the workers and greater availability of the products of their toil to those who produce them. Our soil will be made more fruitful; and those who cultivate it will not only be able to maintain, and even raise the level of, their economic well-being but will become more closely integrated members of the national community. Living in the home will be made easier, more comfortable; and this will serve to strengthen the position of the family as the basic social unit. The nation and its defenses will be strengthened; its resources will be husbanded; and this will contribute not only to national security and defense in the relatively immediate present, but to the welfare of future generations.

Thus strengthened, America need not face its future with dread and fear. War, with all its catastrophic



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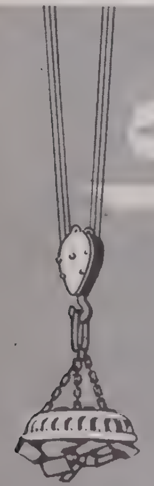
ELECTRICAL INDUSTRY IN AMERICA

(Continued from preceding pa

consequences, need not be looked upon as inevitab and can, with careful guidance, be avoided. By stayi strong and productive, by raising the level of well-bei of its own people and mitigating or eliminating entire social injustices among its citizens, by helping those other countries to reach the same objectives, Ameri can reach a position of influence and respect amo the nations of the earth where it need have no fe of the undermining of its social economic system. T prospect of our present civilization's continuing to ne heights of achievement would thus become brig indeed.

That is the destiny that beckons America. And t electrical industry as I have shown has an unparallel opportunity to help shape that destiny. In that rega its potential influence is out of all proportion to its si to the number of people engaged in it, or to the capit represented by its shops, tools, plants, and equipme It is rather more like fire, between which and electrici —the modern fire—there is a close affinity. Wh Prometheus brought fire to man, he brought what w without doubt the Supreme Gift. With fire in his fu possession man, he felt, would be able to win t secrets and treasures from the earth, to develop scienc commerce, and the arts. Our modern fire has lost no of the potency of the Promethean, nor the potentialiti for improving the welfare of man.



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RESISTANCE-THERMOMETER BRIDGE

Compactness, ease of manipulation, and high accuracy without necessity for thermostatic control are attained in this new bridge

By S. S. STACK
General Engineering & Consulting Laboratory
General Electric Company

FOR precision temperature measurements in resistance thermometry it is the general practice to use a type of Wheatstone bridge as described y Mueller.(1) Precision bridges of this type are usually rovided with some form of thermostatic temperature ontrol and are a means of determining the resistance a detector element independent of the lead resistance. he bridge now to be described* is of this type and can e used with either the three-lead Siemens type or the ur-lead potential-terminal-type resistance elements. ll the coils of major importance in this bridge are of a old-chromium alloy; the other coils are of manganin. he exceedingly low temperature coefficient of resistnce of the gold-chromium alloy eliminates the necessity r thermostatic temperature control and permits a very ompact arrangement. With normal changes in ambient onditions, the accuracy obtained is equal to that of ermostatically controlled precision-type bridges havg all manganin coils.

The remarkable stability and low temperature oefficient of resistance for the gold-chromium alloy dicated that it would be suitable for precise electrical easuring instruments and especially well suited for a recision resistance-thermometer bridge. **Fig. 1** shows ie arrangement used in the design of the bridge; **Fig. 2** ows the schematic circuit. The following are the ajor features:

(1). Provides for a compact arrangement and high accuracy over normal ambient temperature range without thermostatic control

(2). Six dials having a range of 111.111 ohms in steps of 0.0001 ohms. Adjusted in absolute ohms to an accuracy of ±0.01 per cent or 0.0002 ohm, whichever is larger

(3). A three-position plug block with positions for measuring, adjusting ratio arms to equality, and for obtaining the zero reading, (*M*, *R*, and *Z*, respectively)

(4). Adjustable resistor with graduated dial for adjusting the ratio arms to equality

(5). Galvanometer damping resistor with a switch for either series or parallel connection

(6). A two-point selector switch

(7). A commutator for adapting the bridge to four terminal resistors

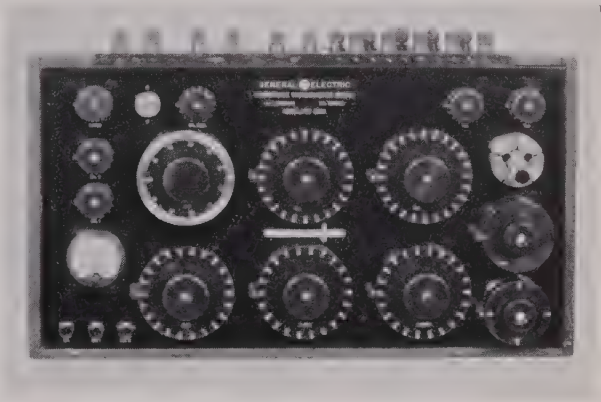

Fig. 1. Resistance-thermometer bridge with its cover removed showing convenient arrangement for connections, settings, and readings

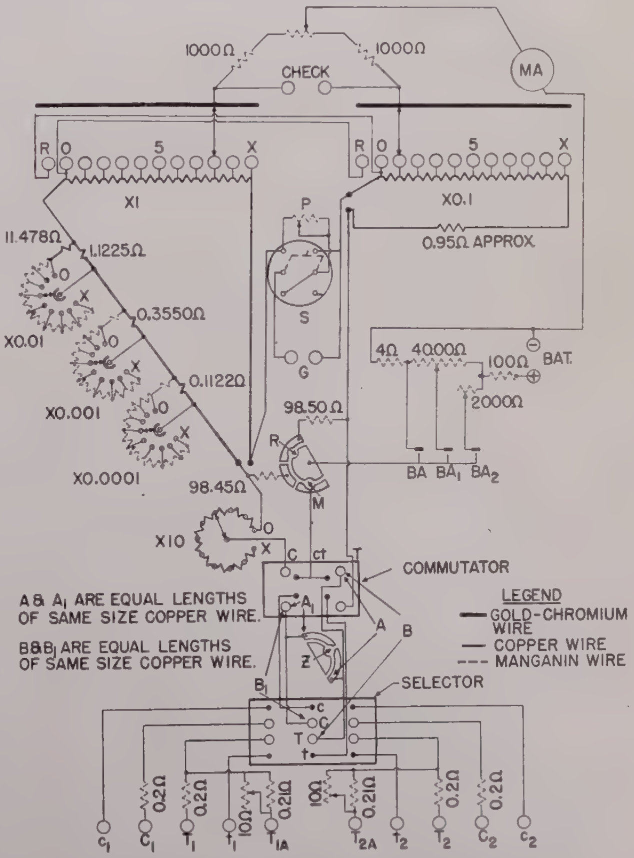

Fig. 2. Schematic circuit for resistance-thermometer bridge

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(1)Numbered references are listed at the end of the article, page 21.
*Not yet available as a commercial instrument.

This article is so paged that, without mutilating other articles, it can be adily removed for filing as a group of full-size consecutive pages.—Ed.

(8). Adjustable resistors in the T_A leads for balancing lead resistances

(9). Battery circuit with an indicating milliammeter, three battery keys, and two adjustable rheostats.

Description of Circuit

The arrangement shown in **Fig. 1** is a top view of this bridge, with its cover removed. All the binding posts are on the back, so that the leads when left connected do not interfere with replacing the cover. The dimensions of the case are 12 in. by 21 in. by 6½ in. in height including the cover. The schematic diagram (**Fig. 2**) shows the gold-chromium coils and wiring in heavy black lines. All the other coils are of manganin; the rest of the wiring is of insulated copper bus wire.

The circuit is of the six-dial decade type, the 1-ohm steps being additive in one arm and the 0.1-ohm steps subtractive in the other arm. This provides for permanent connections to the galvanometer circuit and also puts the contacts of these two dial switches in series with the 1000-ohm ratio arms where possible variations in resistance and thermal emfs are of minor importance. The three decades with steps of 0.01, 0.001, and 0.0001 ohms are shunted decades to minimize the effect of contact resistance. The decade with steps of 10 ohms is connected in such a manner as to be out of circuit when the plug is in the "R" (ratio) position when balancing the ratio arms to equality. The contacts in this decade are of the amalgamated mercury contact type. The two binding posts marked "Check" are provided for checking the equality of the leads to the studs in the ×1 and ×0.1 dials.

When the plug is in the "R" position, resistors are inserted in both the bridge arms, making them approximately 100 ohms each when the ×0.01 dial is set on 5. This brings these arms within normal operating range, and only small galvanometer deflections will be obtained when adjusting the ratio arms to equality. The total range of the ratio adjustment slide wire is 0.02 per cent. The dial is graduated so that each division is equal to approximately 0.001 per cent and permits of setting to an accuracy limited only by the sensitivity of the galvanometer. The "R" positions of the ×1 and ×0.1 dials are used to reverse the ratio arms; the ratio adjustment is set at equality when the same galvanometer deflection is obtained with these dials set on "0" as when set on "R." The leads to the "R" studs are of equal lengths of the same size copper bus wire.

A double-pole double-throw switch in the galvanometer damping circuit is used so that the adjustment rheostat can be used either in series (*S*) or in parallel (*P*) with the galvanometer. The design is such that no disturbing thermoelectric effects are introduced by the rheostat and switch contacts.

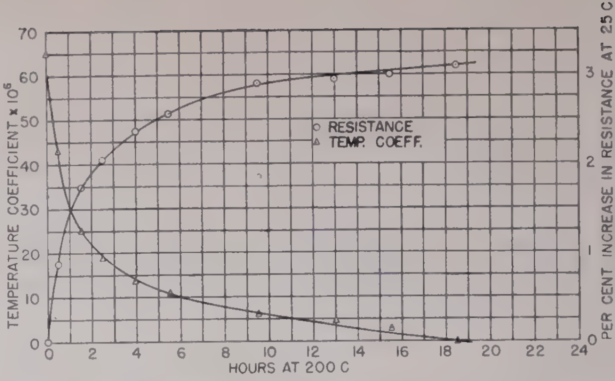


Fig. 3. Change in resistance and in temperature coefficient of resistance produced by heat-treating, for 25-mil gold-chromium wire

The commutator provides a means of measuring the resistance of temperature elements of the four-lead potential terminal type. The mercury contacts in the bridge leads (*CT*) are of the amalgamated plane end-face type(2) as the irregularities in resistance a less than those often occurring with mercury cups. I the battery leads (*ct*) where resistances are of le importance, mercury cups are used. When the com mutator is changed from the normal to the reverse

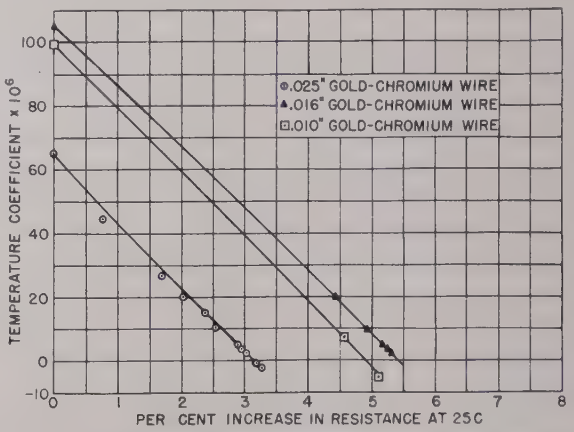


Fig. 4. Linear relationship between resistance at 25 C and temperature coefficient of resistance for gold-chromium wire

position the leads *CT* are interchanged and the batter is transferred from the *c* to the *t* lead. The bridge rea ing is then taken as the mean of the readings obtaine with the commutator in the normal and reversed pos tions, thus eliminating the resistance of the leads fro the final result.

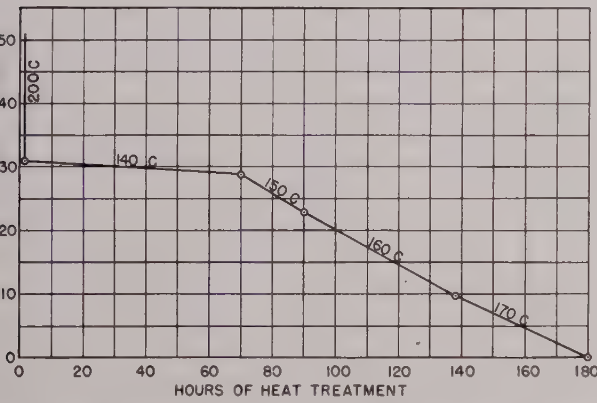
The "zero reading" is obtained for the bridge by pla ing the plug in position "Z." The connecting leads the plug blocks are balanced as shown in **Fig.** and thus a means is provided for obtaining the "ze reading" independent of any connections to the *cC* terminals. The 0.95-ohm resistor is so adjusted th the bridge readings obtained for both positions of t commutator are in the range of zero to 0.0002 oh positive. The mean of these two readings gives the val for the "zero reading" which must be subtracted fro all bridge readings to obtain true bridge readings.

The selector switch is a four-pole double-throw me cury switch with contacts the same as used in t commutator. The circuit from the selector switch the binding posts is made with resistors in the lea as shown in **Fig. 2**. The resistors in the T_{1A} and T leads are made about 0.01 ohm higher than those e T_1 and T_2 leads and are shunted by an adjustable sistor which can be used to compensate for inequal- es of the resistances of the thermometer leads so at for convenience the reading obtained with the mmutator on N can be made very nearly the same with the commutator on R.

The milliammeter in the battery circuit is a 10-ma trument; but inasmuch as the bridge is of the equal- io type and the current divides evenly between the o arms, the scale is graduated to indicate ½ current the thermometer current directly. One battery key ovides a low current for use in making preliminary justments. The current obtained by each of the other ys is controlled by individual rheostats and can be for rated current of the thermometer elements be- measured.

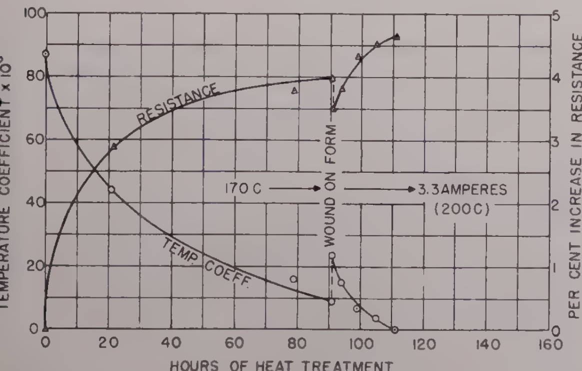
aracteristics of Gold-chromium

The investigation of the properties of gold-chromium oys carried out at the Bureau of Standards(3) showed at about 2.1 per cent of chromium in gold would give alloy that, with suitable heat treatment, could be de to have a negligible temperature coefficient of istance—that is, less than 0.000001 per degree C, the range of 18 to 35 C.



ig. 5. Rate of change in temperature coefficient of resistance at various heat-treating temperatures for 10-mil gold-chromium wire

In the construction of this bridge, three sizes of gold- omium wire are used (0.025-in., 0.016-in., and 0.010-), the composition by analysis being 2.05 per cent chromium in gold. **Fig. 3** shows the changes in istance and in the temperature coefficient of resistance for the 0.025-in. wire as produced by heat treating. **Fig. 4** shows the linear relationship that exists between the increase of resistance at 25 C and the decrease in temperature coefficient during the heat treatment for the three different sizes of wire. The average of the slopes in **Fig. 4** gives a decrease of 20×10^{-6} in the temperature coefficient for a 1-per cent increase in resistance. This compares with values of 26×10^{-6} for an alloy containing 2.35 per cent chromium and 22×10^{-6} for an alloy containing 2.1 per cent chromium.(4)



ig. 6. Effects of winding wire on forms in terms of heat-treatment required for 25-mil gold-chromium wire before and after being wound

The duration of the heat-treating time at 200 C required to reduce the temperature coefficient of resistance to zero is dependent upon the initial state of the wire. It is therefore apparent that an initial heat treatment at 200 C could be made on bare wire to bring the temperature coefficient down to a low value before being insulated for use in winding the coils. A temperature of 200 C is excessive for cotton and silk insulation, and a lower heat treating temperature would be desirable. **Fig. 5** shows the rate of change at various heat-treating temperatures. The curve shows that 170 C is about the minimum practical temperature that can be used during the final heat treating period; therefore glass insulation is preferable to cotton or silk.

Coils wound with glass-insulated gold-chromium wire were found to have a higher temperature coefficient of resistance after winding than that of the wire itself before winding. **Fig. 6** shows the magnitude of this change and the additional heat treatment required after winding. Any work-hardening caused by bending the wire while making adjustments was found to produce this same effect. This characteristic is quite different from that of manganin, where the effect of cold-working due to winding has very little effect on the temperature coefficient of resistance and a subsequent heat treatment at 140 C will relieve the winding strains.

The thermoelectric power of this gold-chromium alloy against copper is 7 microvolts per degree C. This compares with a value of about 2 or 3 microvolts per degree C for manganin against copper.

The resistivity is 32 microhm-cm in the final heat-treated state as compared to a value of about 45 microhm-cm for manganin.

Construction of Resistance Units

The three characteristics of the gold-chromium alloy that renders unsuitable the common designs used for manganin resistance units are:

(1). High thermoelectric power against copper (seven microvolts per deg C.)

(2). Work-hardening

(3). High-temperature heat treatment after winding (170 C).

In both bridge arms shown in **Fig. 2**, the gold-chromium resistors and leads in each arm are continuous, with taps taken off; and the junctions where the ends are joined to copper are brought into close proximity to each other. This arrangement reduces to a minimum the number of gold-chromium to copper junctions in the bridge arms and galvanometer circuit and minimizes thermoelectric effects by placing these junctions in a region of temperature equilibrium.

Figs. 7 and **8** show the design of the two units for the left and right arms respectively. A circular pattern was chosen with the several tapped sections spaced and distributed around the circle so that the ends nearly meet and so that the leads to the switch studs could be short and of equal length. The wire is glass-insulated and after the several taps are attached it is wound bifilar on the coil form and tied down with glass yarn. This method provides mechanical support for the entire length of the alloy wire and prevents any future bending, with its possible work-hardening effects, after final adjustment.

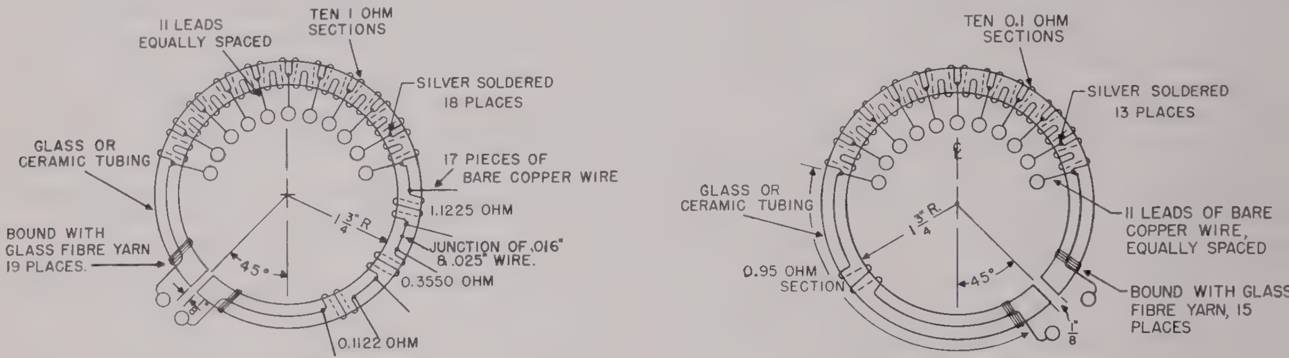

11 LEADS EQUALLY SPACED
TEN 1 OHM SECTIONS
SILVER SOLDERED 18 PLACES
GLASS OR CERAMIC TUBING
17 PIECES OF BARE COPPER WIRE
1.1225 OHM
$1\frac{3}{4}$" R
BOUND WITH GLASS FIBRE YARN 19 PLACES.
JUNCTION OF .016" & .025" WIRE.
45°
$\frac{1}{8}$"
0.3550 OHM
0.1122 OHM
TEN 0.1 OHM SECTIONS
SILVER SOLDERED 13 PLACES
℄
GLASS OR CERAMIC TUBING
$1\frac{3}{4}$" R
11 LEADS OF BARE COPPER WIRE, EQUALLY SPACED
0.95 OHM SECTION
45°
BOUND WITH GLASS FIBRE YARN, 15 PLACES
$\frac{1}{8}$"

Fig. 7. Left-hand unit

Fig. 8. Right-hand unit

Figs. 7 and 8. Construction of gold-chromium resistance units

All units are completely heat-treated and all but the final adjustments made before the units are mounted in the bridge. During the stages of heat-treatment and preliminary adjustment, the units are mounted on suitable test forms that will withstand furnace temperatures. When the furnace heat-treating method has progressed to the point where one or more sections have reached a zero temperature coefficient of resistance, the individual sections are given the desired additional heat-treatment by passing the required current through that section to raise it to the desired temperature. The spacing of the sections is such that this can be done without affecting adjacent sections.

The 11.478 ohm coil and the coils for the ×10 dial are individual coils wound on brass spools insulated with mica. A bifilar winding is used, and both junctions where the copper leads are attached are placed on the same side of the spool rather than on opposite sides in order to minimize thermoelectric effects. After heat treatment and adjustment, both the coils and resistance units are wax-coated for moisture protection.

Accuracy and Precision

The accuracy obtainable with a bridge of this type is independent of the accuracy of adjustment of the individual ratio coils as a means is provided for adjusting to exact equality. The amount of unbalance, if any, between the other two bridge arms is obtained by the "zero reading" and so, being a known value, can be applied as a correction to the bridge reading and enters into the final accuracy by the accuracy to which t "zero reading" is known.

The factors entering into the accuracy and precisi of the bridge are:

(1). Adjustment of the coils

(2). Temperature coefficient

(3). Equalization of the bridge arms and connec ing leads

(4). Stability of contact resistances.

The adjustment of the coils is made at 25 C. The 1 ohm, 1-ohm, and 0.1-ohm steps are adjusted to with 0.01 per cent of their nominal value and the other thr dials are adjusted to be within 0.00001 ohm of th nominal value.

For any temperature between 20 and 30 C, the chan in resistance from that at 25 C for each of the 10-oh coils and for the sum of the ten 1-ohm coils is less tha part per million; and for the sum of the ten 0.1-oh coils, the change is less than 0.00001 ohm. The oth coils wound with manganin wire have a temperatu coefficient of less than 0.000015 per degree C at 25 C.

Equalization of the bridge arms and the amou of copper resistance in each is obtained, as indicat in **Fig. 2**, by using equal lengths of the same si wire. An equality to within 0.0001 ohm is readily tained by this method.

The plug and block are of ample size and stur construction so that, when the surfaces are clean, t variations in contact resistance are of the order 0.0001 ohm. The circuit through the block is such th with the plug in the "R" and "Z" positions, the curre divides to the opposite arms of the bridge through t separate segments thus providing some compensatio In the "M" position, the contact is simply in series the battery circuit where it introduces no error.

Dial-type switches have a probable variable conta resistance of 0.0002 ohm. In the three shunted dia this amount of variance is practically negligible; f example, in the ×0.01 dial, at the zero position whe it is a maximum, the effect is only 0.000002 ohm and correspondingly less in the other two dials.

The effect of the dial contacts of the ×1 and × which are in series with the ratio coils do, however, ha a somewhat larger effect. The 0.0002 ohm in 10 ns equals 0.00002 per cent; and, assuming positive one and negative for the other, the probable varia- in the ratio from unity is 0.00004 per cent, or 1 part 2,500,000.

nmary

suitable design has been obtained for gold-chro- ım resistance units which provides for all the neces- y precautions required to meet the particular racteristics of this alloy. The stability of the resist- e of these units for the first few months is equal that obtained with well-constructed manganin s. For normal changes in ambient temperatures to 30 C) ordinarily encountered in laboratories, accuracy is comparable to that obtained with lges having manganin coils thermostatically con- led. The accuracy of adjustment is 0.0002 ohm or 1 per cent, whichever is larger. A precision of better n 0.0001 ohm is obtainable for low resistances and wo or three parts per million for high resistances.

he covered dials provide protection for the switch tacts so that only occasional cleaning is required. dials are easily manipulated and have positive exing facilities for fast operation. With the exception he ×10 dial, a 180-degree rotation of the dials is all t is required for total range; there are no stops be- een the 10 and 0 points, so that complete rotation possible. The built-in selector switch provides for venient and rapid comparison of two thermometer nents, as often required in standardization work. smaller size, freedom from temperature control, convenience provided in a bridge of this design ke it very particularly suitable for use in labora- es and wherever calorimetric measurements or perature standardization work are being done and h accuracy is required.

erences

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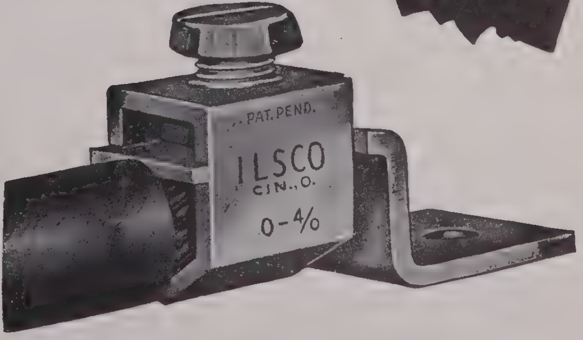

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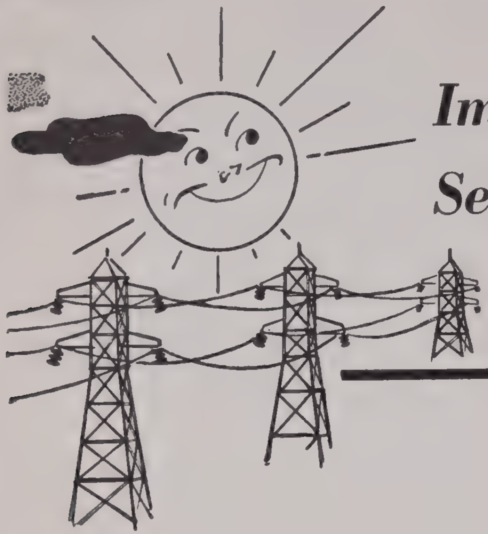

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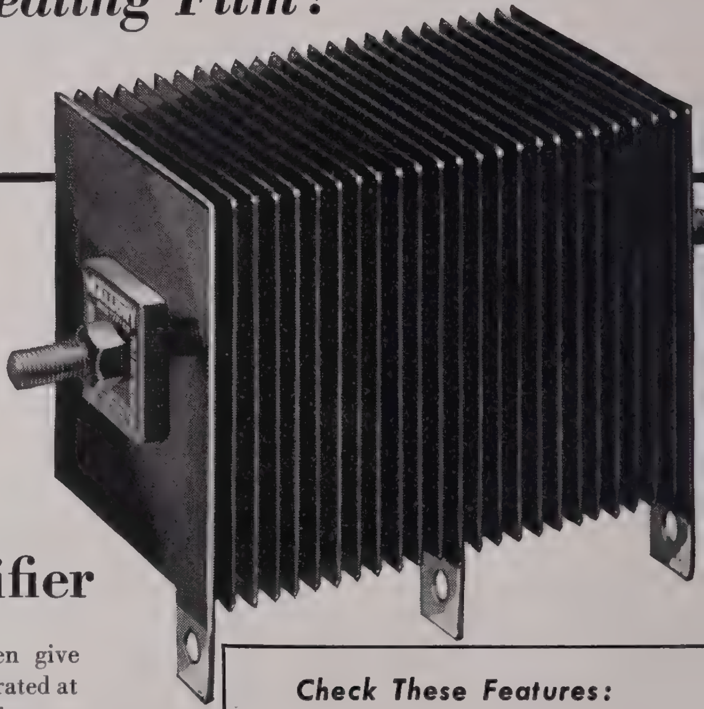

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SELECTION OF D-C SERIES-WOUND MOTORS FOR CRANE APPLICATIONS

Marc de Ferranti

A review of mill-motor characteristics based upon new standard ratings and their effect on hoist applications

By M. A. de FERRANTI
Industrial Engineering Divisions, Apparatus Department
General Electric Company

THERE is an increasing demand for the application of mill-type motors on d-c cranes, both for steel mills and for heavy duty in other ndustrial plants. Although no radical changes have aken place in the design of series-wound d-c motors, t is well, with the adoption of new standards for d-c nill motors, to review their operating characteristics nd to determine how these affect their application to ranes. It is well also to emphasize that the standards dopted by the Association of Iron and Steel Engineers liminated some of the methods of rating previously pplied to mill motors. Open discussion of these changes y engineers interested in the materials-handling ndustry is the surest way to avoid misapplication and o take full advantage of the characteristics built into he new mill motor.

-c Series-wound Mill-motor Characteristics

Fig. 1 shows the characteristics of an MD-610 d-c eries-wound mill motor that is typical of this form of he new line recently standardized by the Association f Iron and Steel Engineers. The new motors are already eing applied extensively on both steel-mill and other eavy-duty cranes. Note particularly that no power ating is given in the caption of this diagram because n order to apply the motor correctly a clear undertanding of the characteristic curves is necessary; nowledge of a nameplate rating representing a single oint on the horsepower curve *HP* and a corresponding point on the speed curve is not sufficient to make a correct application of the motor. Data given by curves in the drawing, however, are sufficient to apply the motor intelligently and predict its performance.

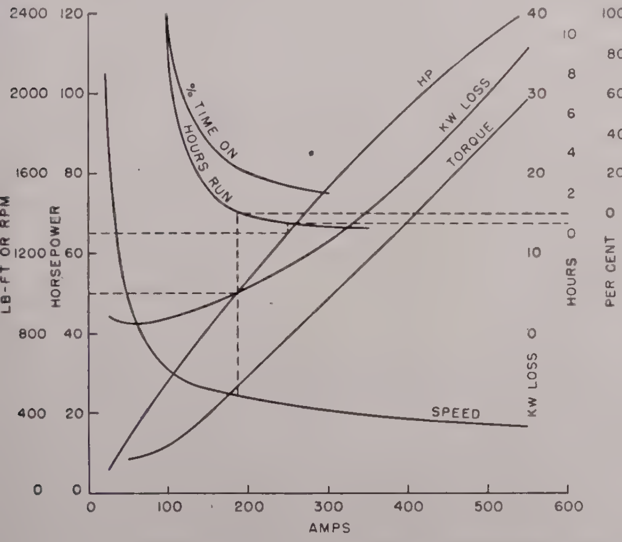

Fig. 1. Characteristic curves for a 230-volt MD-610 series-wound motor

Some data which are readily determined from these curves will bear emphasis by the following comments:

(1). The maximum running torque for the motor is 2100 lb-ft

(2). The maximum safe speed of the motor is 2100 rpm

(3). If run continuously at constant load, this totally enclosed motor will develop 27 hp without exceeding 75 C. At this load its speed will be 630 rpm and therefore its torque will be 225 lb-ft

(4). If run for 60 minutes continuously at constant load the motor will develop 50 hp without exceeding its guaranteed temperature rise. At this load its speed will be 500 rpm and therefore its torque will be 525 lb-ft. If operated on repeated cycles, each of not more than five minutes' duration, the portion of the total time during which it could be run and carry 50 hp would be 23 per cent

(5). The motor could run with a constant load of 65 hp for 30 minutes without exceeding guaranteed temperature rise. On repeated cycles, each of not more than five minutes' duration, the portion of each cycle it could be running and carry 65 hp would be 14 per cent

Similar information could be determined for other load or time conditions, and the motor could theoretically carry any one or all of these ratings on its nameplate without any change in the motor itself. From practical considerations it is desirable to use the minimum number of nameplate ratings but make all operating data available to those in a position to apply the motor. Whether the motor be in its totally enclosed form, its protected self-ventilated form, or its enclosed forced-ventilated form, the speed, torque, and horsepower curves of the motor are the same. Regardless of the nameplate rating on the various forms of the d-c series-wound mill motors, the maximum running torque

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This article is based on material presented first as a report made at a Standardization Session of the 1947 Annual Convention of the AISE, and later as a conference paper at the Materials Handling Session of AIEE 1948 Winter Meeting. We are reproducing it here for the benefit of those of our readers who have not learned of this instructive guide to selecting mill-type motors for crane service.—ED.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—ED.

and commutating peaks to which the machine may be subjected are the same. The thermal ability of the motor changes, however, with the various forms and, consequently, so does its ability to handle duty-cycle operation.

Methods of connecting and controlling the motor so as to modify its speed-torque characteristics and adapt them to crane operation are well known. It is not the intention here to describe in detail the control equipment used or the methods of calculating speed-torque characteristics, but a brief review of the principal methods of modifying the speed-torque characteristics of the series motor is essential to the correct application of motors to crane drives.

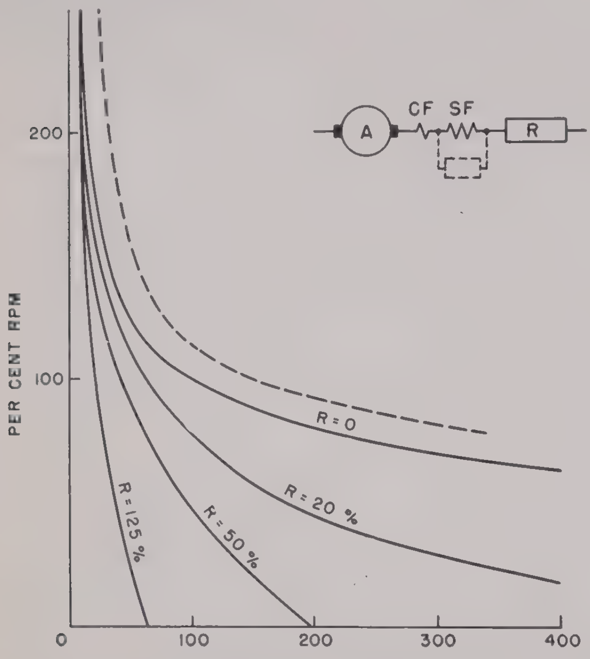

Fig. 2. The addition of line resistance reduces the torque of a d-c series-wound motor as shown

The simplest method of reducing motor torque (not torque per amp) and speed output of a series motor is by addition of resistance in series with the motor. The effects of various values of such resistance are shown in **Fig. 2**. One hundred per cent resistance for a particular motor application is that value of resistance which, with rated voltage applied, and with the armature at standstill, will allow rated motor current to flow. It will be recognized, therefore, that the value representing 100 per cent resistance will vary with the various possible ratings of the same physical motor. For example, if the MD-610, 230-volt motor bears a 60-min rating of 50 hp, the rated current is 184 amp. Then 100 per cent resistance is 1.25 ohms. However, if the same motor bears a 30-min, 65-hp rating, the rated full-load current would be 246 amp, and 100 per cent resistance is 0.935 ohms. The curves shown in **Fig. 2** are based on the 30-min ratings of MD-600 motors. The dotted speed-torque curve corresponds to the dotted connection for shunting the series field. This connection provides a method of obtaining speeds higher than provided by the basic curve of the motor and it is seldom used in crane applications of serie motors. Note that none of the curves shown in **Fig.** cross the zero torque axis; this indicates that the moto speed may become excessive if load torque falls too low

Further modification of the speed-torque characteristics can be effected by the addition of armature-shunting resistance. **Fig. 3** shows speed-torque curve for a series motor having various combinations of lin and armature-shunting resistances. It will be note that the addition of armature-shunting resistance give the motor a positive maximum speed, even when loa is entirely removed from the motor. The armature-shunted connections provide improved speed regulatio even at light loads, and these connections are especiall suitable for slowdown points without resorting t plugging the motor. **Fig. 4** shows the shunt-motor connection of a d-c series-wound motor using various value of line, armature, and series-field resistance. This connection provides dynamic braking and regenerativ braking, and is particularly adaptable to control c overhauling loads. **Fig. 5** combines the curves of **Figs.** **3**, and **4** and shows how they can be used to give th features necessary in hoist control of a d-c series-woun motor. It is not intended that this represent an actua layout of a crane-hoist system, but rather that it sho the type of curves required to satisfy the speed-torqu relationships shown in the schematic diagrams indicating directions of motion and of motor torque fc each quadrant. The solid-line arrows represent direction of motion of the load. The dotted-line arrows sho direction of torque.

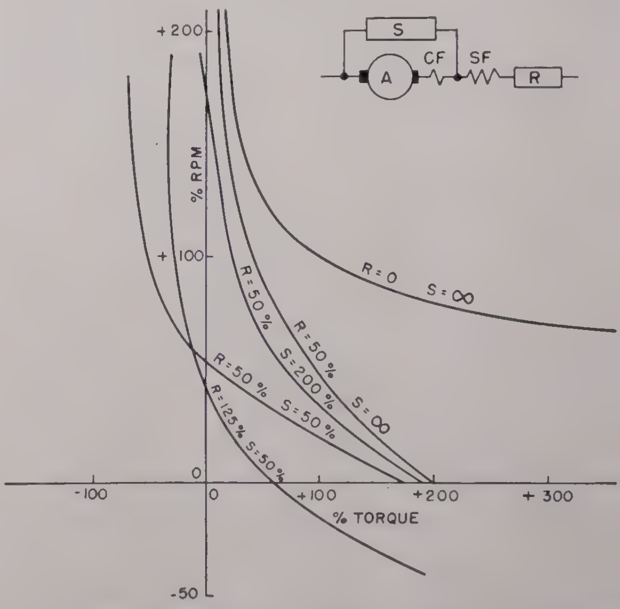

Fig. 3. Effect of line and armature-shunting resistance on speed-torque characteristics of d-c series-wound motor

Hoist-motor and Gear-ratio Selection

For many years, d-c series-wound crane motors ar d-c series-wound mill-type motors have been succes fully applied to hoist motions of cranes on the bas at the 30-min horsepower rating of the motor should e not less than the horsepower required to hoist ecified hook load at specified hook speed. A review of ctors which may affect this practice and consideration the new mill motors in this respect follows:

The advent of roller bearings on motors and hoists, gether with other design improvements which have creased the mechanical efficiency of hoists, emphasizes ne problem of excessive light-hook speeds. Selection hoist gear ratio should be made carefully, and care ould be exercised to avoid overmotoring. As will be emonstrated by the example calculated here, overotoring may well cause excessive light-hook speed, ith the attendant possibilities of overrunning the pper limits. With the elimination of the 30-min rating mill-type d-c motors by the Association of Iron and eel Engineers, it is important that electrical engineers alize the relationship between the 60-min rating hich the motor bears and the crane-hoist load to which may be applied. Table I shows a comparison of the)-min ratings and 30-min capacity of the new totally nclosed d-c series-wound 230-volt mill motors.

Suggestions have been made that d-c series-wound otors bearing a 30-min rating should continue to be pplied on crane-hoist motions so that horsepower utput of the motor does not exceed this rating when ne hook is hoisting specified load at specified speed. or mill-type motors bearing a 60-min nameplate ting, the horsepower load on the motor should not xceed 1.33 times the nameplate rating when the hook hoisting specified load at specified speed. In general rms, mill-type d-c series-wound motors should be pplied to crane hoists so that the torque loading on ne motor when the hook is hoisting specified load at pecified speed is not greater than 40 per cent of the otor's maximum guaranteed running torque. For example, consider the application of a d-c series-wound mill-type motor to the hoist motion of a crane on which the following data apply:

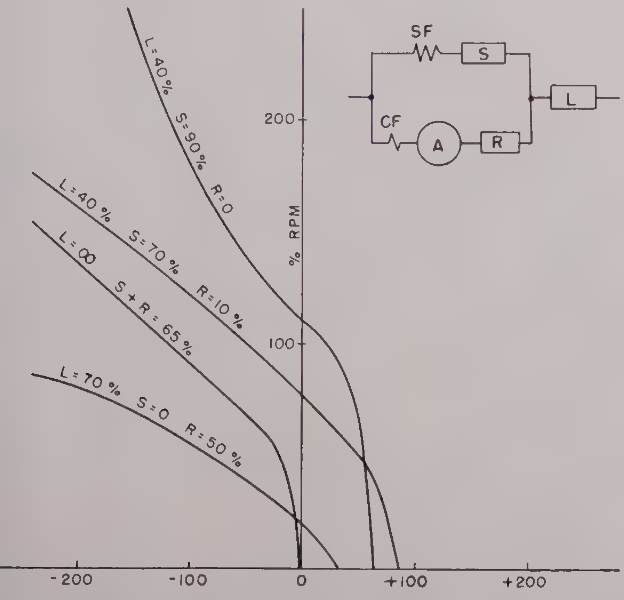

Fig. 4. Speed-torque characteristics of d-c series-wound motor when operated as a shunt motor

Weight of hook with specified load	31,000 lb
Specified hook speed	50 fpm
Mechanical efficiency of hoist	0.85

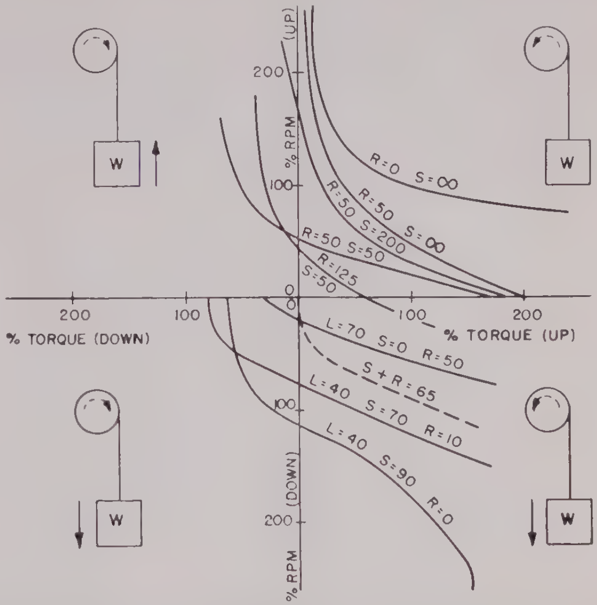

Fig. 5. Speed-torque characteristics of d-c series-wound motor operating the hoist motion of a crane

Then the horsepower output of the motor to hoist specified load at specified speed is given by:

$$\text{Hp} = \frac{31{,}000 \times 50}{33{,}000 \times 0.85} = 55$$

and a d-c series-wound mill motor having a 30-min rating not less than 55 hp or a 60-min rating of not less than $\frac{55}{1.33} = 41.3$ hp should be used. Such a motor is the MD-610, for which characteristics are shown in **Fig. 1**. Reference to **Fig. 1** indicates that for a 55-hp output the MD-610 series-wound motor has a speed of 480 rpm and that, if operated on repeated cycles each of five minutes or less, the motor may carry this load for 19 per cent of the total time. Gearing should be selected so that 480 rpm on the motor shaft corresponds to 50-fpm speed of the hook. By calculation, or from the torque curve in **Fig. 1**, the motor-shaft torque corresponding to specified load on the hook is 600 lb-ft.

Assume that when hoisting an empty hook the motor torque is reduced to 15 per cent of the full-load hoisting torque—that is, to 90 lb-ft. Then from the speed and torque curves of **Fig. 1** it will be noted that motor speed is 900 rpm; this means that the light hook will travel up at 187 per cent of specified speed; i.e., at 93.5 fpm.

Table II considers the use of several different motors on the hoist drive of this example.

This tabulation indicates that if severe duty on the hoist requires more thermal capacity than is provided by the totally enclosed MD-610, there are several ways in which this can be secured:

(1). Use of the same frame size while changing to the protected, self-ventilated form of the mill motor. This increases the "per cent time on" from 19 to 57 for the 55-hp load without any change in speed-torque characteristics.

(2). Use of the same frame size, with the force-ventilated features including motor-driven blowers mounted on the mill motor, and with or without filters. This increases the "per cent time on" for the 55-hp load to 85 per cent without any change in speed-torque characteristics.

(3). By the use of the next larger frame size (612) of totally enclosed series mill motor the per cent time on for the 55-hp load and on duty-cycle work is 43. However, the light-hook speed is higher as a percentage of specified speed, and because the Wk^2 value of the larger motor is higher, the stored energy in the motor armature when hoisting with a light hook is almost three times that for the MD-610 in any one of its three forms. The significance of this high stored energy lies not only in the increased energy which must be supplied to the motor but, more important, in the fact that this energy must b dissipated in order to stop the hook in its upwar travel. This causes increased duty on the motor dynamic braking is used, and also increases the dut on holding brakes, which are set very rapidly whe making a stop of travel in the hoisting directio Especially does the increase of stored energy becom an important factor in the selection and setting the overhoist limit switch.

In addition to the foregoing alternative selections new 600-series motors, two ratings of Type CO e closed, series-wound crane motors have been tabulate The CO-1830 high-speed motor would handle the 55-h load from a torque standpoint, but for the low torqu required to hoist a light hook this motor would reac an unsafe speed. Such high speeds are reached only the hoisting distance is sufficient for the motor accelerate fully. The use of a larger (CO-1831) mot gives safe light-hook speeds, but it is interesting to no that the stored energy during light-hook operation considerably less with the MD-610 than with either the CO motors. It is clear also from the low "per cen time on" values for the CO motors that these are n as good for duty-cycle operation as mill-type motors.

TABLE I

COMPARISON OF 60-MIN RATING AND 30-MIN CAPACITY OF D-C SERIES-WOUND MILL MOTORS

Motor	Max Running		60-min Rating			30-min Capacity			$\frac{Hp_{30}}{Hp_{60}}$*	$\frac{T_{30}}{T_{60}}$*	$\frac{T_{30}}{T_m}$*
	Torque	Rpm	Hp	Rpm	Lb-ft	Hp	Rpm	Lb-ft			
MD-602	196	3600	7½	800	49	10	675	78	1.33	1.59	0.397
MD-603	288	3300	10	725	72	13½	610	116	1.35	1.61	0.402
MD-604	484	3000	15	650	121	19	600	166	1.27	1.37	0.343
MD-606	912	2600	25	575	228	33	515	336	1.32	1.47	0.368
MD-608	1400	2300	35	525	350	45	470	503	1.28	1.44	0.365
MD-610	2100	2100	50	500	525	65	445	767	1.30	1.46	0.465
MD-612	3320	1900	75	475	830	100	430	1220	1.33	1.47	0.368
MD-614	4560	1700	100	460	1140	135	400	1775	1.35	1.55	0.390
MD-616	7000	1600	150	450	1750	200	400	2630	1.33	1.50	0.362
MD-618	10,000	1500	200	410	2560	265	385	3620	1.32	1.41	0.362

* The last three column headings have the following significance:

$\frac{Hp_{30}}{Hp_{60}}$ is the ratio of the 30-min horsepower capacity to the 60-min horsepower rating of the motor.

$\frac{T_{30}}{T_{60}}$ is the ratio of the 30-min torque capacity to the 60-min torque rating of the motor.

$\frac{T_{30}}{T_m}$ is the ratio of the 30-min torque capacity to the maximum torque ability of the motor.

TABLE II

COMPARISON OF MILL AND CRANE MOTORS FOR HOIST DRIVE

Motor	Form	30-min Capacity or Rating	60 min Rating	Rpm at 55 Hp	Permissible Per Cent Time on at 55 Hp	Wk^2	Motor Rpm for Light Hook	Per Cent of Specified Hook Speed	Stored Energy in Motor (hp-sec) Light Hook Up
MD-610	Enclosed	65 hp, 445 rpm	50 hp, 500 rpm	480	19	72	900	187	18.2
MDP-610	Protected		62½ hp, 460 rpm	480	57	72	900	187	18.2
MD-610	Separate blower	Continuous rating 50 hp. 500 rpm		480	85	72	900	187	18.2
MD-612	Enclosed	100 hp, 500 rpm	75 hp, 475 rpm	550	43	118	1200	218	53.0
CO-1830	Enclosed	65 hp, 700 rpm	47 hp, 850 rpm	760	7	52.4	2100	*276	72
CO-1831	Enclosed	75 hp, 500 rpm	55 hp, 600 rpm	600	12	95.2	1450	242	62.5

* This speed exceeds the safe maximum speed for the CO-1830 motor.

Although "per cent time on" values are an accurate ndication of the motor's ability to handle duty-cycle peration when the load throughout the "time on" is onstant, the watts-loss method of determining the hermal capacity of the motor must be used when the oad varies during the "time on." This method has been ublicized by manufacturers of the mill- and crane-type notors and consists briefly of the following:

> Determine from the motor characteristic curves the watts loss for each value of load; then compute the total watt-seconds loss during the "time on" period and determine the average watts loss over the same period. The "per cent time on" corresponding to this value as shown by the motor curve should be greater than the percentage ratio of the running time to total cycle time. For force-ventilated d-c mill motors operating on duty cycles, current values for the various loads during a cycle can be determined from the motor characteristic curve and an rms current value determined for the total cycle time (full ventilation is provided whether the motor is running or at rest). If this current value is less than the current corresponding to the motor's continuous rating—which is equal to the 60-min rating of the enclosed motor—the cycle can be repeated continuously without overheating the motor.

ridge and Trolley Drives

The inherent speed-torque characteristics of d-c eries-wound motors are particularly suited to the cceleration of heavy masses, such as crane bridges and rolleys. The use of the motor in conjunction with series esistance provides a convenient means of limiting the cceleration-torque peaks during acceleration and also ontrolling deceleration by plugging the driving motors. y the addition of an armature-shunting connection, is possible to provide a positive maximum speed and lso give the travel good slowdown and creeping speed haracteristics. The subject of control and methods of alculating resistance layouts for designed speed-torque urves lies outside the scope of this article, but the eneral features and effect of various values of resist-nce are readily noted in **Fig. 6**. This shows the four peed-torque quadrants and indicates schematically he direction of motion and of motor torque for each uadrant. It can be seen that the motor and resistor onnections shown meet all of the requirements for ontrol of the bridge or trolley motion.

The selection of the correct series-motor rating and ear ratio to give the required rates of acceleration and uaranteed running speed is affected by many variables. Vith changes in mechanical design, particularly the se of antifriction bearings, and with the adoption of ew standards for d-c mill motors, it seems desirable to eview some of the factors which determine the selection f d-c series motors for bridge and trolley drives.

The force necessary to drive the bridge or trolley onsists of that necessary to overcome rolling friction nd that required to accelerate or decelerate the crane.

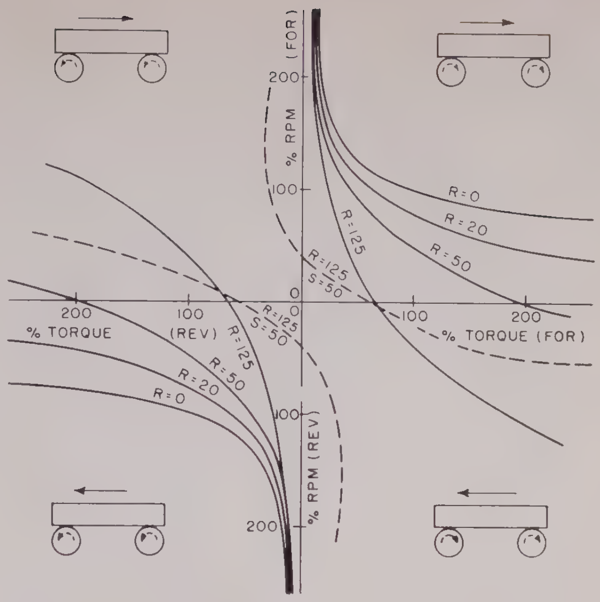

Fig. 6. Speed-torque characteristics of d-c series-wound motor operating the bridge or trolley motion of a crane

The rolling friction is proportional to the total weight and is assumed to be constant at all speeds of travel of the bridge or trolley; it is generally expressed in terms of pounds per ton weight of the bridge or trolley and in the following analysis is denoted as f. The force required to accelerate the bridge or trolley is equal to its mass times its rate of acceleration. The acceleration is denoted as a and is generally expressed in terms of feet per second per second. These are two of the variables (f and a) which enter into any consideration of bridge and trolley drives.

The function f is determined by the mechanical design of the crane and rails, and varies from values as high as 30 lb per ton for some sleeve-bearing drives down to as low as 6 lb per ton for some roller-bearing drives which have been tested. The rate of acceleration a refers, in the case of d-c bridge and trolley drives, to that part of the acceleration in which the motor has resistance in series, and which is being cut out in steps by magnetic contactors or by a drum switch. During this period several steps of control are provided to give an average constant torque until all resistance is cut out; after that, the accelerating rate is determined by the characteristic curve of the motor. The accelerating rate maintained by the average constant torque produced by the motor while on the resistor is the maximum which occurs during acceleration. This value is limited by considerations of wheel slippage, hook swing, and operator comfort (for cab-operated cranes) and is more significant than any average which might be taken over the full time for the drive to come up to speed.

Corresponding to these linear forces, the torque delivered to the driving wheels of the bridge by the motor comprises that necessary to overcome rolling friction and that required to accelerate the mass of the bridge. These torques, expressed as T_g and T_a respectively, are both functions of the bridge weight, and for the range of rolling friction and accelerating rates encountered in practice can be combined into a single factor. That factor also takes into account the approximately constant shape of the speed-torque curve for all ratings of series-wound MD-600 motors. It also takes into account the upper limit of torque to which the motor may be subjected while the accelerating resistor is in the circuit. Experience has indicated the upper limit of torque as 200 per cent of the 60-min torque rating of the motor, which is 133 per cent of the 30-min torque rating or 50 per cent of the maximum running torque of the motor.

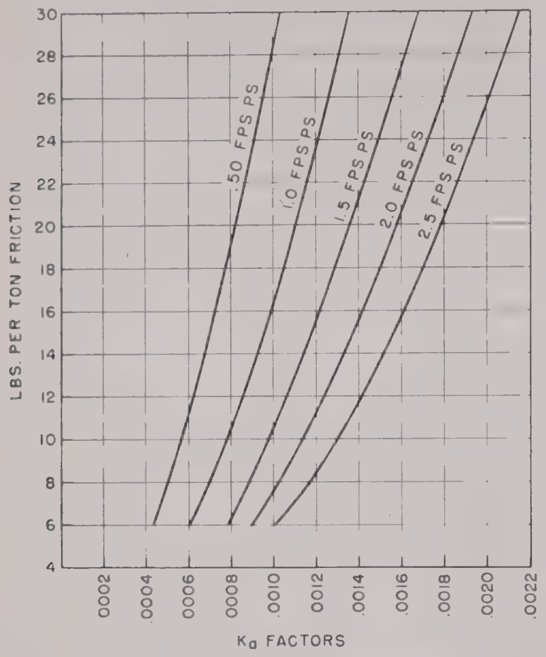

Fig. 7. The K_a factors for various values of friction and accelerating rates on crane trolleys and bridges

The single factor known as the accelerating factor (K_a) also includes the numerical constants necessary to convert our variables to horsepower rating. The values of this K_a factor for practical conditions of rolling friction and accelerating rate are shown in **Fig. 7**.

It is possible to use these K_a factors to determine the minimum horsepower rating of a suitable enclosed Type MD series-wound bridge motor by the formula

$$\text{Hp (60 min)} = \frac{K_a \times W \times V}{E}$$

in which W is the bridge weight in tons (including load), V is the specified bridge speed in feet per minute, and E is the mechanical efficiency between driving wheels and motor shaft. The factors here reviewed and a simple example of bridge-motor selections are shown in **Fig. 8**.

The preceding formula will give the theoretical minimum horsepower rating of the enclosed MD motor required. The nearest standard rating above this value should be used. After selecting the standard enclosed MD motor, gearing should be selected by computing the free-running horsepower and then referring to the characteristic curves of the actual motor to be used. Read the motor speed in relation to the free-running horsepower value; then select gear ratio so that this corresponds to specified bridge speed.

Thus far, the selection does not take into account heating of the motor, but before considering this it will be well to review an example of motor selection by the formula just presented.

Consider an overhead steel-mill crane which has a total weight of 77 tons when loaded and has a specified bridge speed of 350 fpm. Assume that the mechanical efficiency between axle and motor shaft is 0.9, the rolling friction is 21 lb per ton, and the accelerating rate required while on the resistor is 2 fpsps. According to **Fig. 7** the K_a factor is 0.00160. Then

$$\text{Hp (60 min)} = \frac{K_a WV}{E}$$

$$= \frac{0.00160 \times 77 \times 350}{0.9} = 48.0$$

This calls for a 50-hp (60-min rated) MD-610 motor.

Now,

$$\text{free-running hp} = \frac{77 \times 21 \times 350}{33{,}000 \times 0.9} = 19.5$$

Referring to the characteristic curve of MD-610 motor, **Fig. 1** indicates that the corresponding speed is 770 rpm, and gearing should be selected such that this motor speed corresponds to 350 fpm bridge speed. The motor torque at this point (which is T_g)

$$= \frac{19.5 \times 5250}{770} = 133 \text{ lb-ft}$$

The 60-min torque rating of this motor is 525 lb-ft, and by definition it can be used at twice this value while accelerating the bridge on the resistor—that is, at 1050 lb-ft. Then the torque available for acceleration is

$$1050 - 133 = 917 \text{ lb-ft}$$

Approximate torque to accelerate motor rotor and brake wheel is as follows:

Wk^2 of motor = 72; Wk^2 of brake wheel = 24 approximately. Speed when resistor is cut out is approximately $\frac{350 \times 0.8 \times 500}{770} = 182$ fpm.

$$\text{Time to reach this speed} = \frac{182}{60} \times \tfrac{1}{2} = 1.5 \text{ sec.}$$

Torque to accelerate motor and brake

$$= \frac{96 \times 400}{308 \times 1.5} = 83 \text{ lb-ft}$$

Therefore net torque available for bridge acceleration is $917 - 83 = 834$ lb-ft. The corresponding force F_a, available for acceleration, is $\frac{2\,T_a GE}{D}$

in which G = total gear ratio between truck axle and motor shaft and D = diameter of truck wheel in feet. Therefore F_a = 10,400 lb when the gearing is so selected that 770-rpm motor speed corresponds to 350 fpm, for which condition $\frac{G}{D}=6.91$. Consequently $a=\frac{F_a\times g}{W}=\frac{10{,}400\times 32.2}{154{,}000}=2.17$ fpsps, which is a little better than specified.

For a determination of the motor's ability to meet a particular frequency of operation, there is no accurate method except a duty-cycle calculation. A typical duty-cycle calculation for a bridge drive using the MD-610 motor is given under Motor Heating Calculations, immediately following.

Motor Heating Calculations

To calculate the heating of the motor, the duty cycle on which the crane will operate must be predicted. For example, it will be assumed that the crane considered in the example under Bridge and Trolley Drives makes repeated bridging motions that cause the bridge to accelerate to free-running speed; the bridge is then decelerated by a hydraulic brake. The load is then removed from the hook and the crane returned to its starting point.

Assumptions

Crane specified load = 15 tons
Crane weight including load = 77 tons
Specified bridge speed = 350 fpm
Rolling friction per ton = 21 lb
Accelerating rate while on resistor = 2 fpsps
Mechanical efficiency = 0.9

Gearing and motor rating will be as previously determined, namely MD-610, and $G/D=6.91$.

Calculations

The equivalent Wk^2 value of bridge at motor shaft =

$$\frac{154{,}000}{0.9\times 39.6}\left(\frac{350}{770}\right)^2=895 \text{ lb-ft}^2$$

Adding motor and brake, $Wk^2=991$ lb-ft²

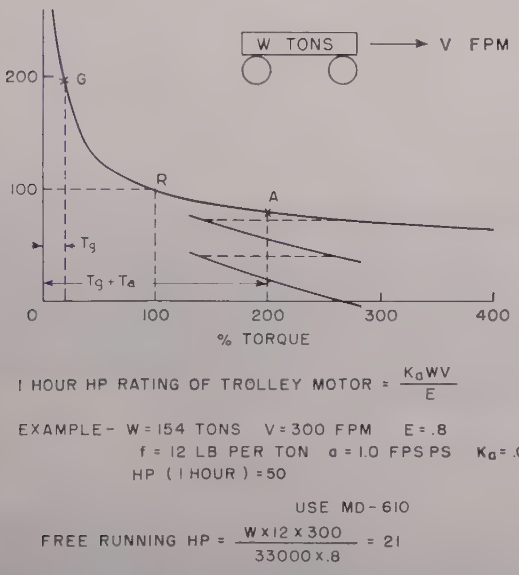

Fig. 8. Selection of d-c series-wound motor rating and gear ratio for the hoist and trolley drives of a crane. Gearing is selected to give *V* fpm for motor rpm of 730 at 21 hp taken from the motor curve

With this information, and by reference to the motor characteristic curves, it is now possible to calculate time, distance traveled, and motor losses during acceleration of the bridge from standstill to full speed. This will be done in steps as follows:

(1). With motor on resistor—that is, from 0 to 400 rpm on motor.
(2). From 400 to 500 rpm on motor.
(3). From 500 to 600 rpm on motor.
(4). From 600 to 700 rpm on motor.
(5). From 700 to 770 rpm on motor.
(6). From 770 rpm to 0 on motor shaft. Deceleration by hydraulic brake. Motor disconnected.

This is computed for the outward trip of the loaded crane and the return trip of the unloaded crane.

(1). 0 to 400 rpm.

While on resistor, average motor torque is twice 60-min-rated torque

= 2×525 = 1050 lb-ft
Free-running torque = 133 lb-ft
Net torque available for acceleration = 917 lb-ft

Time to accelerate to 400 rpm $=\frac{991\times 400}{308\times 917}=1.4$ sec

Average bridge speed $=\frac{350\times 400}{770\times 2}=91$ fpm

Distance traveled $=\frac{91}{60}\times 1.4=2.13$ ft

Average motor loss (from curve) = 13 kw
Total loss during acceleration = 13×1.4 = 18.2 kw-sec

(2). 400 to 500 rpm

Corresponding bridge speeds = 182 to 227 fpm
Average bridge speed = 204.5 fpm

Average motor torque $=\frac{1050+525}{2}=787.5$ lb-ft

Net accelerating torque = 787.5 − 133 = 654.5 lb-ft

Time to accelerate $=\frac{991\times 100}{308\times 654.5}=0.491$ sec

Distance traveled $=\frac{204.5}{60}\times 0.491=1.67$ ft

Average motor loss (from curve) = 8.5 kw
Total loss during acceleration = 4.18 kw-sec

Similarly subsequent increments can be computed. The results are shown in Table III.

For the return trip, the equivalent Wk^2 value of the bridge and the free-running torque are reduced according to the dropping of the load. There will be some full-speed running of the unloaded crane to cover the full return distance, as shown in the tabulation.

Conclusion

The above review of series mill-motor characteristics and the examples given demonstrate that the mill motors may be applied to crane motions on the following basis:

(1). For hoist drives the smallest enclosed motor applied should be such that the hp required to hoist

TABLE III

DUTY-CYCLE CALCULATION

	Rpm	Final Fpm	Avg Fpm	Time on Sec	Total Sec	Feet Traveled	Total Distance	Avg Kw Loss	Kw-sec
Out trip—loaded									
Accelerate on resistors	0–400	182	91	1.4	1.4	2.13	2.13	13	18.20
Accelerate on motor curve	400–500	227	204.5	0.495	1.895	1.67	3.80	8.5	4.20
Accelerate on motor curve	500–600	272	249	1.195	3.090	4.95	8.75	3.5	4.18
Accelerate on motor curve	600–700	318	295	3.32	6.410	16.30	25.05	2.0	6.64
Accelerate on motor curve	700–770	350	332	13.65	20.060	75.60	100.65	1.5	20.50
Decelerate on brake	770–0	0	175	2.92	22.98	8.50	109.15	0	0
Return—unloaded									
Accelerate on resistor	0–400	182	91	1.13	1.13	1.72	1.72	13	14.70
Accelerate on motor curve	400–500	227	204.5	0.39	1.52	1.33	3.05	8.5	3.32
Accelerate on motor curve	500–600	272	249	0.897	2.417	3.72	6.77	3.5	3.14
Accelerate on motor curve	600–700	318	295	2.160	4.567	10.60	17.37	2.0	4.32
Accelerate on motor curve	700–850	386	352	10.90	15.467	64.00	81.37	1.3	14.20
Run at full speed	850	386	386	2.71	18.177	17.43	98.80	1.1	2.98
Decelerate on brake	850–0	0	193	3.22	21.397	10.35	109.15	0	0

Total time for round trip =44.377 sec
Total kw seconds loss =96.38 kw-sec
Motor "time on"=20.060 +18.177 =38.237 sec
Average kw loss =2.52
Allowable "per cent time on" =50 for an average kw loss of 2.52 from curve, **Fig. 1.**
Time per cycle =76.475 sec, required if motor is not to overheat.

Time available for deceleration, lowering and raising hook, loading and unloading during each cycle =38.237 sec, which is 50 per cent of the total cycle time. Approximately 47 round trips per hour can thus be made without overheating the motor, and this may be carried on continuously.

With the data given in the tabulation, speed-time, and speed-distance, diagrams can be plotted for the bridging motion of the crane. This is particularly desirable for consideration of other cycles which may be performed by the same bridge drive.

specified load at specified speed is not greater than the 30-min capacity of the motor. This is equivalent to 1.33 times the motor's 60-min-hp rating, and the corresponding motor torque is approximately 40 per cent of the maximum running torque of the motor.

(2). For bridge or trolley drives the smallest enclosed motor applied should be such that its 60-min rating is not less than that given by formula:

$$\text{Hp (60 min)} = \frac{K_a\,WV}{E}$$

or the 30-min rating should be not less than 1.33 times this.

(3). In both cases the motor selection should be checked from a heating standpoint if repeated duty cycles are to be performed. Except for borderline cases, the motor characteristic curves give sufficient information for making such a check, and the motor manufacturers are always ready to make a check of any application on which complete data are available.

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ANUFACTURERS OF ELECTRONIC DEVICES AND SHEET METAL FABRICATION

THE ELECTRICAL EQUIPMENT FOR 5000-HP GREAT NORTHERN ELECTRIC LOCOMOTIVES

. . . Part II . . .

By H. S. OGDEN, Control Division, Erie Works
and
L. H. BURNHAM, Power Transformer Division, Pittsfield Works
General Electric Company

Alternating-current Main Circuits

The 11,000-volt primary of the locomotive's main transformer receives its power from two pantographs through a current transformer for the primary protective relay. The low side of the main transformer primary is solidly grounded through two additional current transformers; one is for the locomotive wattmeter, and the other for the primary protective relay.

The secondary of the main transformer supplies power at 1358 volts to the two main synchronous motors and at 237 volts to the motor-alternator sets. The electrical center of the transformer secondary is grounded through a grounding autotransformer.

The individual main sets are brought up to 55 per cent speed by means of two starting generators supplying power to the main generators which act as motors during the starting period. At 55 per cent speed the synchronous motor is connected to the 883-volt ta on the main transformer, and the set continues t accelerate with the synchronous motor acting as a induction motor. When full speed is reached, fiel excitation is applied to the motor. After the set has bee pulled into step by the application of the field, th voltage on the motor is changed from 883 to 1358 volt the normal running voltage of the machine. Startin of each main set requires that the starting generator on each of the two auxiliary motor-alternator sets b operated in parallel to provide enough power to tur over the sets and accelerate them. Thus, it is necessar to start the two main sets consecutively, and contr interlocking is provided to insure that this will occu The power circuits for starting are shown in the mai circuit schematic diagram, **Fig. 15**.

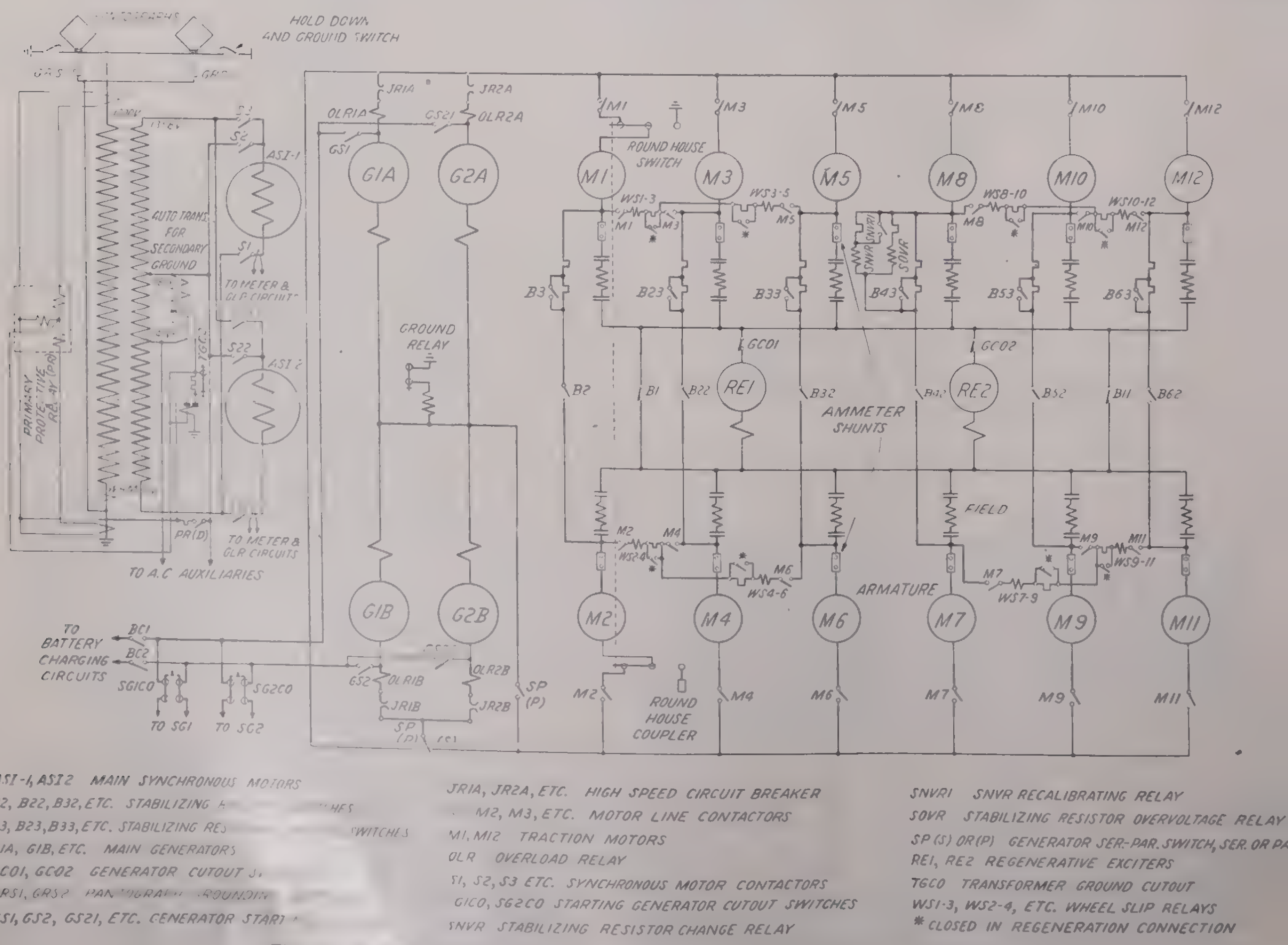
PANTOGRAPHS
HOLD DOWN AND GROUND SWITCH
GRS1
GRS2
S3
S2
AS1-1
AUTO TRANS. FOR SECONDARY GROUND
S1
TO METER & GLR CIRCUITS
S22
AS1-2
TGCO
PRIMARY PROTECTIVE RELAY (PR)
PR(D)
TO METER & GLR CIRCUITS
TO A.C AUXILIARIES
TO BATTERY CHARGING CIRCUITS
BC1
BC2
SG1CO
SG2CO
TO SG1
TO SG2
JR1A
JR2A
OLR1A
GS21
OLR2A
GS1
G1A
G2A
GROUND RELAY
G1B
G2B
GS2
OLR1B
OLR2B
JR1B
JR2B
SP (P)
SP (P) (S)
M1
M3
M5
M8
M10
M12
ROUND HOUSE SWITCH
WS1-3
WS3-5
WS8-10
WS10-12
SNVR1
SNVR
SOVR
B3
B23
B33
B43
B53
B63
GCO1
GCO2
B2
B1
B22
RE1
B32
AMMETER SHUNTS
B42
RE2
B52
B11
B62
FIELD
M2
M4
WS2-4
M6
WS4-6
ARMATURE
M7
WS7-9
M9
M11
WS9-11
ROUND HOUSE COUPLER
AS1-1, AS12 MAIN SYNCHRONOUS MOTORS
B2, B22, B32, ETC. STABILIZING
B3, B23, B33, ETC. STABILIZING RES SWITCHES
G1A, G1B, ETC. MAIN GENERATORS
GCO1, GCO2 GENERATOR CUTOUT S
GRS1, GRS2 PANTOGRAPH GROUNDIN
GS1, GS2, GS21, ETC. GENERATOR START
JR1A, JR2A, ETC. HIGH SPEED CIRCUIT BREAKER
M2, M3, ETC. MOTOR LINE CONTACTORS
M1, M12 TRACTION MOTORS
OLR OVERLOAD RELAY
S1, S2, S3 ETC. SYNCHRONOUS MOTOR CONTACTORS
G1CO, SG2CO STARTING GENERATOR CUTOUT SWITCHES
SNVR STABILIZING RESISTOR CHANGE RELAY
SNVR1 SNVR RECALIBRATING RELAY
SOVR STABILIZING RESISTOR OVERVOLTAGE RELAY
SP (S) OR (P) GENERATOR SER.-PAR. SWITCH, SER. OR PA
RE1, RE2 REGENERATIVE EXCITERS
TGCO TRANSFORMER GROUND CUTOUT
WS1-3, WS2-4, ETC. WHEEL SLIP RELAYS
* CLOSED IN REGENERATION CONNECTION

Fig. 15 Main circuit schematic diagram of the 5000-hp Great Northern locomotives

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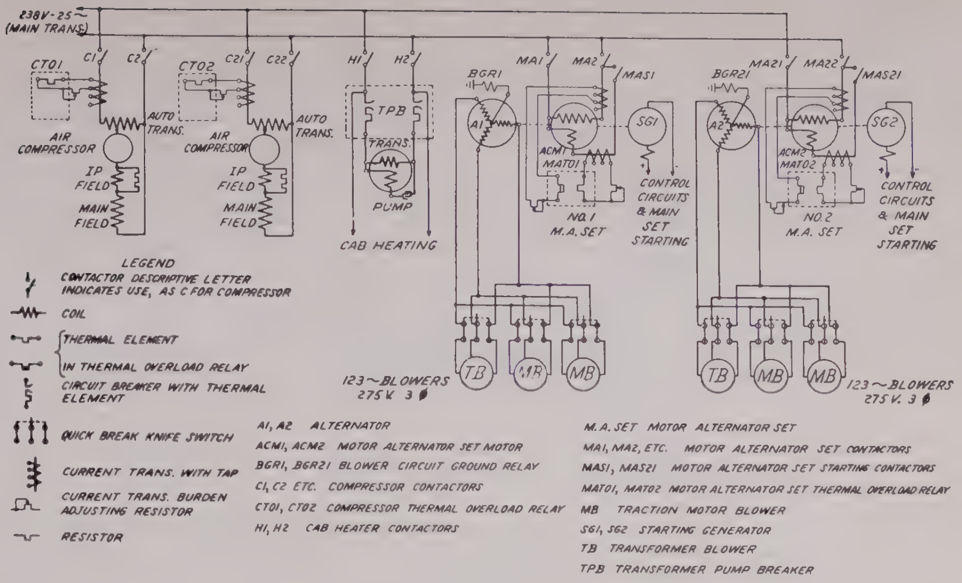
238V-25~ (MAIN TRANS.)
C1
C2
CTO1
CTO2
C21
C22
AUTO TRANS.
AIR COMPRESSOR
IP FIELD
MAIN FIELD
H1
H2
TPB
TRANS.
PUMP
CAB HEATING
BGR1
MA1
MA2
MAS1
A1
SG1
ACM1
MATO1
NO. 1 M.A. SET
CONTROL CIRCUITS & MAIN SET STARTING
BGR21
MA21
MA22
MAS21
A2
SG2
ACM2
MATO2
NO. 2 M.A. SET
TB
MB
123~BLOWERS 275V. 3 ϕ
LEGEND
CONTACTOR DESCRIPTIVE LETTER INDICATES USE, AS C FOR COMPRESSOR
COIL
THERMAL ELEMENT
IN THERMAL OVERLOAD RELAY
CIRCUIT BREAKER WITH THERMAL ELEMENT
QUICK BREAK KNIFE SWITCH
CURRENT TRANS. WITH TAP
CURRENT TRANS. BURDEN ADJUSTING RESISTOR
RESISTOR
A1, A2 ALTERNATOR
ACM1, ACM2 MOTOR ALTERNATOR SET MOTOR
BGR1, BGR21 BLOWER CIRCUIT GROUND RELAY
C1, C2 ETC. COMPRESSOR CONTACTORS
CTO1, CTO2 COMPRESSOR THERMAL OVERLOAD RELAY
H1, H2 CAB HEATER CONTACTORS
M.A. SET MOTOR ALTERNATOR SET
MA1, MA2, ETC. MOTOR ALTERNATOR SET CONTACTORS
MAS1, MAS21 MOTOR ALTERNATOR SET STARTING CONTACTORS
MATO1, MATO2 MOTOR ALTERNATOR SET THERMAL OVERLOAD RELAY
MB TRACTION MOTOR BLOWER
SG1, SG2 STARTING GENERATOR
TB TRANSFORMER BLOWER
TPB TRANSFORMER PUMP BREAKER

ig. 16. The auxiliary circuit schematic diagram

Alternating-current Auxiliary Circuits

The auxiliary alternating-current circuits (**Fig. 16**) upply power to the two compressors and two motor-lternator sets. The compressors operate at 150 volts vhich is supplied through an autotransformer from the 37-volt bus. The autotransformer has saturating haracteristics at high current which limit the inrush urge to the compressor motors during starting.

The two motor-alternator sets start as split-phase nachines. The centrifugal speed switch opens the tarting winding contactor when sets are up to 80 per ent speed, and they continue to run thereafter as ingle-phase machines. This switch also indicates that he two motor-alternator sets are "on the line," and t is then permissible to start the main sets. The control s so arranged that the output of the alternators is cut ff during the main-set starting sequence because the ets are not capable of furnishing power to the blowers nd starting a main set simultaneously.

The d-c generators of the motor-alternator sets are lways operated in parallel. They are regulated to hold 5 volts when charging the battery. When starting a nain set, they are operated up to 150 volts with in-erent machine characteristics, utilizing a series lifferential-field winding to limit the starting current o acceptable values.

irect-current Excitation Circuits

The excitation circuits (**Fig. 17**) are separate and listinct from all other circuits on the locomotive. Normally, the two 45-volt exciters are operated in eries for supplying current to the synchronous-motor ield, main-generator fields, and regenerative-exciter ields. Each of these groups of fields is connected in eries. Center-point connections are provided so that vhen one motor-generator set is shut down, the emaining set will receive its excitation at normal oltage. A generator cut-out switch provides means of utting out the various shunt fields when a given main et is shut down.

Locomotive acceleration is controlled by varying a resistor in the main-generator field circuit. Since the system of switching the main generators from series to parallel requires a change in shunt-field polarity on one generator of each set, the generator series-parallel switch provides for field reversing on the generators involved.

A set of resistors in the regenerative-exciter shunt-field circuit controls the regenerative-exciter shunt field.

The amount of synchronous motor field current is varied by means of contacts on the master-controller main drum so that optimum field strength is available for the average load condition in the various notches.

Direct-current Propulsion Circuits

The direct-current propulsion circuits (**Fig. 15**) consist of the four main generators, 12 traction motors, and the two regenerative or traction-motor exciters and their connections.

The two main-generator armatures of each set are permanently connected together. The circuits are arranged to connect all four armatures in parallel for low-speed operation, or for high-speed operation to

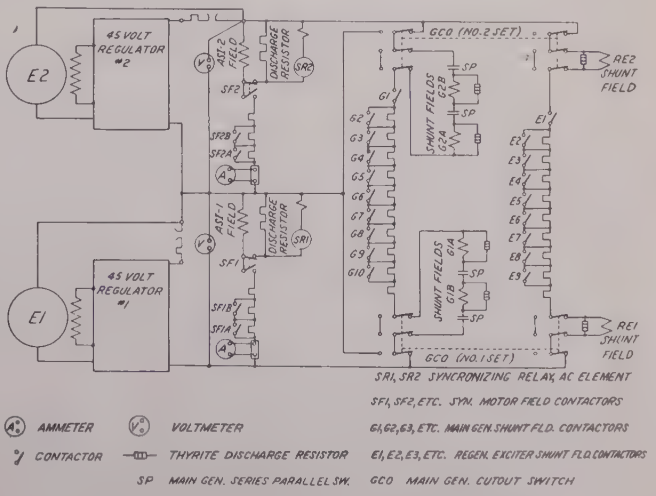

Fig. 17. The excitation circuit schematic diagram

connect two groups in series, each group composed of two armatures in parallel. The change in connections is made on an open-circuit basis; that is, it is necessary for the operator to make his selection of connections with the traction-motor power off. For light-freight duty or passenger-train operation, the locomotive can be accelerated from standstill and operated at all speeds in the high-speed connection.

The traction motors are connected in two groups of six motors in parallel. In the series-excited motoring connection, these two groups are connected in series. This connection provides for the maximum adhesion possibilities which can be obtained from the characteristics of the parallel connection.

In the separate-excitation connection, braking switches B1 and B11 (**Fig. 15**) are open. Opening of B1 and B11 switches connects the traction-motor exciters RE1 and RE2 into the traction-motor field circuit. However, before the separate-excitation circuit is completed, stabilizing-resistor switches B2, B22, B32, B42, and B52 must be closed. This is done by the operator after the voltage across the switches is adjusted to zero by means of the separate-excitation handle on the master controller.

The traction-motor stabilizing-resistor circuit is unusual in that an automatic change in the ohmic value is made when the locomotive floats from braking to motoring or vice versa. The change consists of increasing the resistance to increase the electrical stability of the locomotive when motoring with weak field in the separate-excitation connection. The second benefit of this provision is to decrease the unbalanced motor current in the separate-excitation connection that may be occasioned by variations in wheel sizes. The main-circuit schematic diagram of the stabilizing resistors is shown in **Fig. 18**. The actual change in resistance takes place when the current in the stabilizing resistor is near zero; that is, when the field current is slightly higher than the armature current.

Associated with the separate-excitation connection is the provision which has been made for circulating commutator-conditioning current in the regenerative exciter when it is not otherwise in use. This machine is a relatively low-voltage machine (maximum 25 volts); hence, the commutator condition has a distinct bearing on the permanency of the exciter characteristics. Current in the brushes provides a certain lubricating action that is very beneficial in preventing commutator scour, thus preventing a change in the commutator contact drop which would alter the over-all exciter characteristics. When the high-speed d-c breaker is closed and the locomotive is not in the separate-excitation connection, commutator-conditioning current flows through the short-circuited regenerative-exciter armature.

Main Control Circuits

The locomotive is of the double-end type with an operating cab at each end. Multiple-unit control makes it possible to operate the two units from either of the two operating positions.

The essential equipment in each operating cab is duplicated. **Fig. 19** shows the arrangement of the master controller, brake stand, meters, and air gages. The master controller, in addition to the forward and reverse lever, has three operating handles. The main handle controls the voltage of the main generators which gives direct control of train speed. Whether the operation is to be in the high-speed or low-speed connection of the main generators is determined by the selector handle. The separate-excitation handle, when used, establishes the connections for the use of the regenerative exciter and thereafter controls the strength of the traction-motor fields.

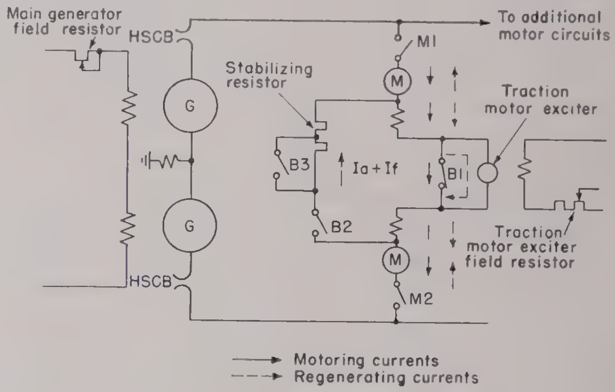

Fig. 18. Fundamental d-c circuits illustrating use of stabilizing resistor

The push-button station contains push buttons for operating:

Pantographs
Blowers
Emergency motor-generator set stop
High-speed circuit breaker
Emergency pantograph ground (for use if all other means of clearing locomotive fail)

The indicating-lamp panel contains bull's-eyes which indicate:

High-speed circuit breaker open
Blowers stopped
Ground fault
Generator overvoltage
Pantograph relay operation
Wheel slip
Hot transformer
Battery not charging
Separate excitation

Except for the separate-excitation lamp, all indicators are dark in normal operation, and become illuminated only when attention is required. The indicators are novel in that when dark they carry their lettering on a white background. When illuminated, the background changes to the appropriate color, depending on the urgency of the attention required. For instance, lights indicating wheel slip, breaker trip, and relay trip turn to red, and those indicating battery not charging or blower stop turn amber.

The meter panel in front of the operator has six internally illuminated instruments and two air gages of the conventional type. The indications provided are:

Equalizing volts
Synchronous motor amperes
Locomotive speed
Generator volts
Traction motor field amperes
Traction motor armature amperes

The intensity of the meter illumination is controlled by the adjusting rheostat. The meters are arranged with white lettering on black background, and use is made of the light transmitting powers of Lucite to transmit light to all parts of the meter scale with a very pleasing effect.

The meter transfer switch is arranged to transfer readings of traction motor armature amperes, traction motor field amperes, equalizing volts, and synchronous motor amperes from each of the three motor circuits on one end of the locomotive to the instruments in front of the operator. A fourth position on the switch will select the circuits being utilized for indication at the operator's position not in use. The main schematic diagram (**Fig. 15**) shows that field-ammeter shunts are connected into the power circuits of half of the traction motors, while the armature ammeters are connected into the power circuits of the other half of the traction motors. Thus, when in the series-excited traction-motor connection, the current flowing in any individual motor can be read.

In either of the traction-motor connections, operation of the meter transfer switch at the operator's unused position by someone other than the operator makes it possible for the operator to read traction-motor and synchronous-motor currents for both halves of the locomotive.

The meter transfer switches can be left in any given position so that if any circuit is overloaded, or the circuit corresponding to the normal position of the meter transfer switch has been cut out, any desired circuit may be observed continuously. This arrangement assures successful operation with all functions when traction motors or a motor-generator set is cut out.

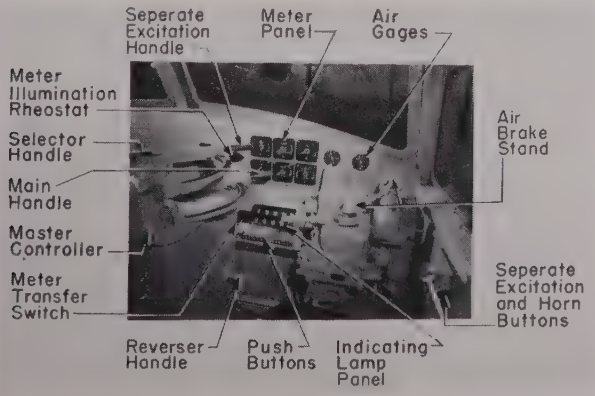

Fig. 19. The arrangement and identification of controls and instruments at the operator's position

On the bulkhead in back of the operator's position in each operating cab, there is a trolley voltmeter, an excitation circuit (45-volt) voltmeter, and a synchronous-motor field ammeter. A battery voltmeter in the No. 2 operating cab and a synchronous-motor temperature indicator in the No. 1 operating cab complete the operating-cab metering equipment.

A foot-operated sander switch, push buttons for establishing separate excitation or series excitation of the traction motors, control breaker, miscellaneous switches for the main and oscillating headlights, and a palm-operated horn button complete the electrical controls provided at the operator's position.

In addition to the two operating positions, there is a starting station from which the compressors and motor-alternator and main sets are started. This station is centrally located in the apparatus cab so that the operation of the main sets can be observed during starting operations. At this station is a set of indicating lights arranged to indicate whether any blower is stopped (and which one of the six), whether a ground relay has tripped, and whether the ground cut-out switch has been operated. To facilitate checking the operation of the blowers, a "blower-start" button has been included. To operate the latter, it is first necessary to have a "blower-run" button closed at one of the main operating positions.

Protective Equipment

The protective equipment on the locomotive consists of the following:

(1). Primary protective or pantograph relay and associated circuits
(2). Ground relays
(3). High-speed breakers for d-c propulsion circuits
(4). Overload relays
(5). Overvoltage relays
(6). Thermal overload relays
(7). Distribution and control circuit breakers
(8). Air relays
(9). Overspeed protection
(10). Slip relays
(11). Emergency stop buttons

Pantograph Relay

The primary protective or pantograph relay is a primary differential and overload relay of the shaded-pole motor-element type for operation from the current transformers in the primary circuit of the main transformer. It is also connected to operate should a ground occur on any of the 25-cycle a-c circuits. The relay is arranged to open all 25-cycle contactors; but, if this does not clear the trouble, the relay will close a switch grounding the pantograph and tripping the track breakers in the substations. When fault current ceases to flow, the relay will lower the pantograph and lock it in the down position until the relay is reset. In the event of extreme urgency, the ground element of the relay can be desensitized by operating a ground cut-out switch. This will permit the locomotive to be operated with one ground fault on the a-c system but with no protection against further grounds.

Ground Relays

A ground relay will trip the d-c power if a ground fault occurs on the d-c propulsion circuits. This can be cut out of the circuit if a ground in the traction-motor circuits prevents this relay from remaining closed.

Another ground relay will indicate the presence of a ground fault on the 45v/90v main-excitation circuits.

Other ground relays, one for each of the two 123-cycle blower systems, will trip off the blower system in which it is connected. The ground fault on the blower system involved must be cleared; or, if the fault is in a blower motor, that motor must be cut out before system operation can be re-established.

High-speed Breakers

Direct-current circuit breakers of the high-speed trip-free type are provided for each of the four generators. They are so arranged that the bucking-bar element of the breaker is effective for a motoring fault when all four generators are in parallel. When the generators are series-parallel connected, half the breakers give protection against a motoring fault and the other half against a regenerating fault. In all cases, the breakers are "backed up" by means of overload relays mounted on bus bars leading to the breakers. Thus, no matter what the type of fault, the breaker will clear, either with its inherent tripping characteristics or with the aid of a bus-bar overload relay.

Overload Relays

The synchronous motors are protected by overload relays of the motor-element type that are operated from current transformers, and are applied to protect against overload and not faults. When the relays operate, the corresponding set is removed from the line but is permitted to resynchronize immediately. Load cannot be reapplied to the traction motors until the high-speed circuit breakers are reset. Protection against a fault is provided by the ground element of the pantograph relay.

Another overload relay augments the protection afforded by the molded-case breakers in the 25-cycle 237-volt heater and transformer-pump circuits where the interrupting capacity of the breakers is less than possible fault currents on short circuits. The overload relay operates to open the line contactors, which have ample interrupting capacity.

Provision has also been made for an overload relay to protect the battery-charging starting generators when they are charging and carrying the control load.

Overvoltage Relays

The low-current motoring section of the stabilizing resistors is protected by an overvoltage relay that when operated will trip the high-speed circuit breakers.

Another overvoltage relay operates in conjunction with the generator voltmeter for the purpose of lighting a warning indicator in front of the operator when maximum voltages are reached.

Thermal Overload Relays

Thermal-characteristic overload relays protect the motor-alternator sets and compressors. These relays use special saturating current transformers. The current-transformer ratio and thermal elements of the relays have been chosen to match the thermal characteristics of the machine windings and thus protect against overloads and faults. The relays are two-element devices, and, for the motor-alternator sets, one element protects the starting winding and the other the running winding of the induction motor.

Distribution and Control Circuit Breakers

There is only one pair of fuses used on the locomotive, and these protect the voltmeter and watthour-meter potential coils. Protection for all 75-volt d-c circuits is provided by molded-case breakers. Individual heater circuits are also protected by molded-case breakers.

Air Relays

Air relays have been provided for each blower. They are of the diaphragm type and are connected to measure static pressure, suction pressure, or both, as required to give successful operation of the relay on the blower involved. The relays operate the indicating lamps, and they will trip the alternator field contactors on loss of air, such as might be occasioned by a bearing seizure, blower failures, etc. Further protection for the blowers is afforded by the blower-circuit ground relays. During starting, the air relays are short-circuited by the blower-start button and blower-start relay.

Overspeed Protection

An overspeed switch will trip the control circuits of each motor-generator set in the event of overspeed which might occur by a trolley circuit outage during regeneration.

The locomotive overspeed warning, controlled by the speed recorder, operates at 55 mph to sound an alarm, and at 60 mph to operate a power trip and cause brake application.

Slip Relays

A slip relay for each traction motor operates to light an indicator in front of the operator should any wheel slip. The relays have been made effective in both motoring and in regenerating. Their operation depends on a difference in current in the traction-motor fields which is caused when a slip occurs.

Emergency Stop Buttons

Emergency stop buttons for the two motor-generator sets have been conveniently located in the two aisles nd in each operating cab of the locomotive. The uttons stop only the set in difficulty, although the mergency stop button in front of the operator will top both sets.

Provision for Emergency Operation

This locomotive is well equipped for emergency peration. A hand-operated cam switch makes it ossible to operate on either one of the two motor-enerator sets with reduced traction-motor output. By sing a small hand-operated selector switch on each nd of the locomotives, it is possible to operate with ny combination of motors cut out down to one remainng pair. Regeneration and separate excitation can be btained with any or all motors on the No. 1 end cut ut and any two pairs of motors cut out on the No. 2 nd.

Although it is impossible to start either main set vith one motor-alternator set shut down, it is possible o shut one motor-alternator set down after the main ets have been started. The remaining motor-alternator et will operate one set of blowers and charge the attery.

Each blower motor is provided with an enclosed ut-out switch of the knife-blade type. When the switch s in the cutout position, it deactivates the air relay for he particular blower involved. When the blowers are ut out, the locomotive must be operated with due egard for the equipment which lacks the ventilating ir.

Operation of the Locomotive

To accelerate the locomotive in the series traction-otor connection, the main handle is notched out in he conventional manner with a thumb button to elease the handle between notches. Since the first otch is dead, being provided for braking only, the perator must move the handle to the second notch efore power is applied to traction motors. The opertor can then continue to notch in accordance with his equirements until he decides to establish the separate-xcitation connection.

The next move is to advance the separate-excitation andle to the notch E and note that the separate-xcitation lamp is illuminated. This indicates that the 1 and B11 switches have taken their proper position pen) and that they have cut the regenerative exciters nto the traction-motor field circuits.

The operator then moves the separate-excitation andle to notch No. 1 and notes that the equalizing oltmeter indication is low. He continues to notch the andle until the equalizing voltmeter indicates zero olts, at which time he presses the separate-excitation utton and the connection is completed by the closure f switches B2, B22, B32, B42, B52, and B62.

If the operator wishes to regenerate, he continues to dvance the separate-excitation handle, building up the raction-motor fields and causing the traction motors o pump power back into the main generators.

Should the operator wish to continue motoring with a weak traction-motor field, as would be required to keep the synchronous motor fully loaded up to a higher train speed, he will back off on the separate-excitation handle.

To re-establish the series-excitation connection, the operator first causes the locomotive to motor, if it is not doing so. After adjusting the traction-motor field current to equal the armature current by manipulating either or both the main and the separate-excitation handles, he presses the series-excitation button. The stabilizing-resistor switches then open, leaving the regenerative exciter in the circuit. The operator must then move the separate-excitation handle slowly toward the OFF position, noting that the separate-excitation lamp is extinguished before notch No. 1 is reached to indicate switches B1 and B11 have opened and the locomotive is back in the original connection. He can then complete the movement of the handle to the OFF position.

Initial Operation in Service

Although these locomotives are very similar in many respects to older Great Northern locomotives, they embody several important differences of detail. The initial operation of the locomotives was very successful, the chief obstacles to be overcome being in the settings of some of the relays, corrections for which were quickly made.

Best train operation, whether freight or passenger, is obtained when the high-speed connection is used on the lighter grades and the low-speed connection is used on the heavier grades. This is true except for the very light passenger trains when the high-speed connection is used throughout the entire run. On runs started in the high-speed connection, there is no difficulty in changing to the low-speed connection on the light-grade sections before the heavier grades are reached. However, a considerable loss in train speed will be occasioned if a change from the low-speed to the high-speed connection is made, once an up-grade has been started.

As in all electric locomotives, the control of the actual load on the locomotive is manual and not automatic. There are stretches of considerable length of uniform grade on the railroad; thus, once the proper setting of levers is made, the locomotive will run for extended periods without readjustment of controller handles. When desired, slowdowns for curves, etc. are easily made by notching out a few points on the separate-excitation handle.

Starting tests show the value of the equivalent parallel connection of the motors as a means to prevent wheel spinning. All observed wheel slip has been of the inching or creeping variety, which is easy to stop by the application of sand or notching off one or two points. On the heavy grades where there is frequent 10-deg track curvature, creeping will start at 15 to 16 per cent adhesion. Where the curvature is less, higher adhesions can be obtained.

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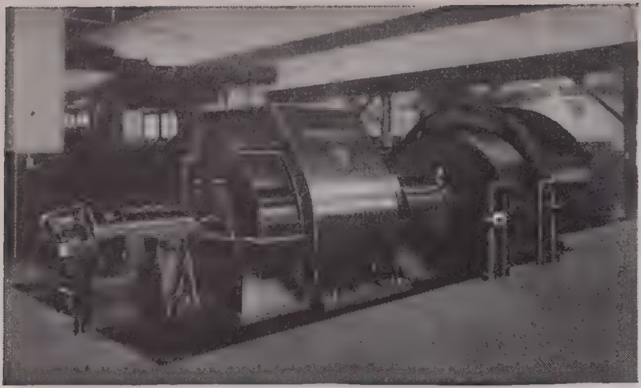

9,000 hp Synchronous Motor, manufactured at C-G-E Peterborough Works, driving a centrifugal compressor at a large Canadian nickel mine.

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GENERAL ELECTRIC REVIEW
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EQUIPMENT FOR 5000-HP LOCOMOTIVES

(Continued from preceding page)

The operation of the slip relays, both in the serie connection of the traction motors and in the separate excitation connection, has been very successful.

The extreme care which was exercised in the desig stages to balance the various traction-motor cable runs by the use of special cable-length compensatin resistors, appears to be well rewarded. As a consequence, the current balance between all traction-moto circuits, particularly in the separate-excitation connection, is exceptionally good. On a test run durin which the two locomotives were operated in multipl very satisfactory load balance between the two unit was obtained.

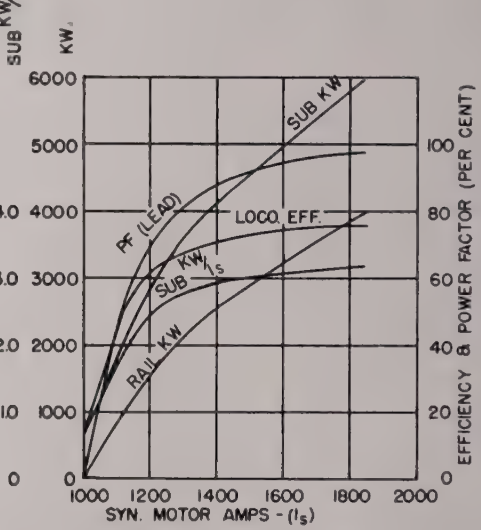

Fig. 20. The locomotive performance curves over the range covered by main controller handle notches 18 to 39 with 11,000 volts on trolley

The curve in **Fig. 20** shows the over-all locomotiv performance on the Great Northern electrification The curve shows the synchronous-motor amperes i the load-control range of the main handle of the maste controller in relation to

(a). Rail kilowatts (average over operating range o traction motors and generators)

(b). Locomotive efficiency, with all losses for (a above

(c). Locomotive power factor

(d). Substation output in kw

Item (d) was derived from road tests in which one o the new locomotives was operated with an old locomotive on a train of known weight and which was the only train on the system at the time. Because the olde locomotive characteristics were well known, th efficiency of the new locomotive from the train t frequency-changer stations was accurately obtained This curve forms a basis for the load dispatching o trains when the new locomotives are used.

(Concluded)

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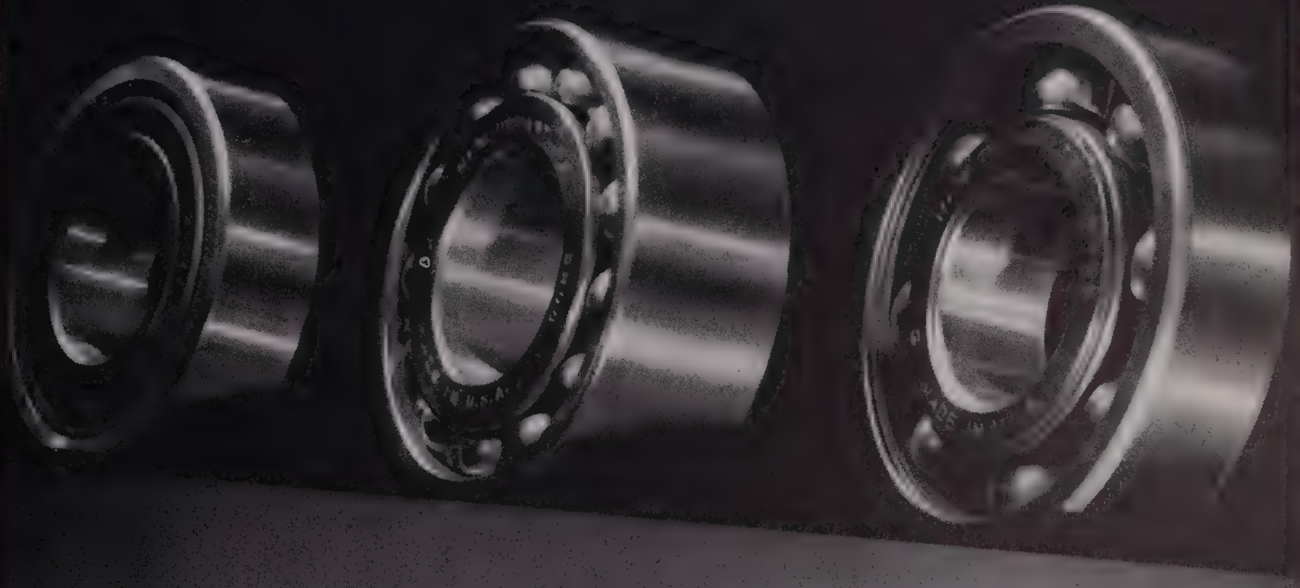

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TRENDS IN AIR CONDITIONING AND REFRIGERATION

. . . Part II . . .

The problems that are encountered point to the need for more widespread and accurate knowledge of basic architectural and equipment requirements. Such a correlation of knowledge by the home and equipment builders would undoubtedly be of benefit to the users of the equipment and to the industries concerned

By W. E. JOHNSON
Air Conditioning Department, General Electric Company

EQUIPMENT design is broadly influenced by economic trends and by the rate of advance made in solving fundamental problems. It is also influenced by new things learned from research. The following is presented as an analysis of the trends in design of some of the major components of air-conditioning and refrigerating equipment.

Reciprocating Compressors

Over a number of years the question of the most economic dividing line between reciprocating and centrifugal compressors has slowly been resolved. The answer, it now appears, places the line of division at about 200 hp, the upper limit for compressors using Freon refrigerants, with centrifugal equipment being used above that horsepower. For ammonia equipment the same question has not been raised, and there is no economic limitation in evidence on the size of reciprocating compressors for refrigerating plants using ammonia.

In the line of Freon compressors, the trend has been slowly toward larger horsepower for the past fifteen years, starting originally with top sizes of approximately 10 hp. Sizes are now up to the 100-hp and 200-hp range.

Another trend in compressor design that has yet to reach a final conclusion is the increasing size range of hermetically sealed compressors. These are compressors in which the driving motor is enclosed (**Fig. 3**) along with the compressor in a sealed case. Their great advantage is the elimination of the shaft seal that is otherwise necessary. However, because larger machines are not as sensitive to small leaks, the hermetically sealed compressor does not maintain its advantage as the size is increased. This problem has been answered by some manufacturers by furnishing designs that have an enclosed motor without hermetically sealing the entire assembly, thus leaving critical areas, such as head and valve plates, accessible for service.

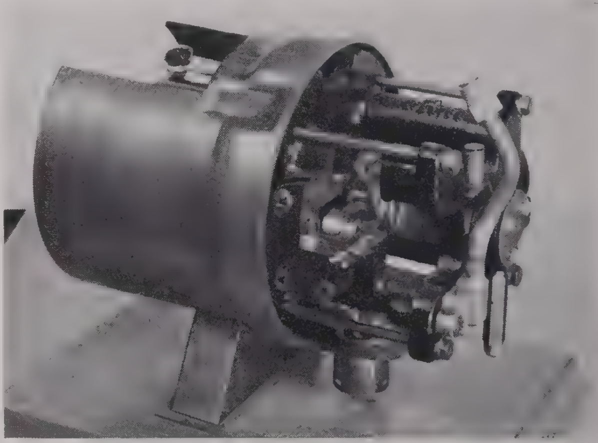


Fig. 3. Cutaway view of hermetically sealed compressor

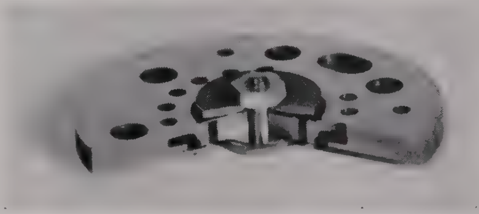
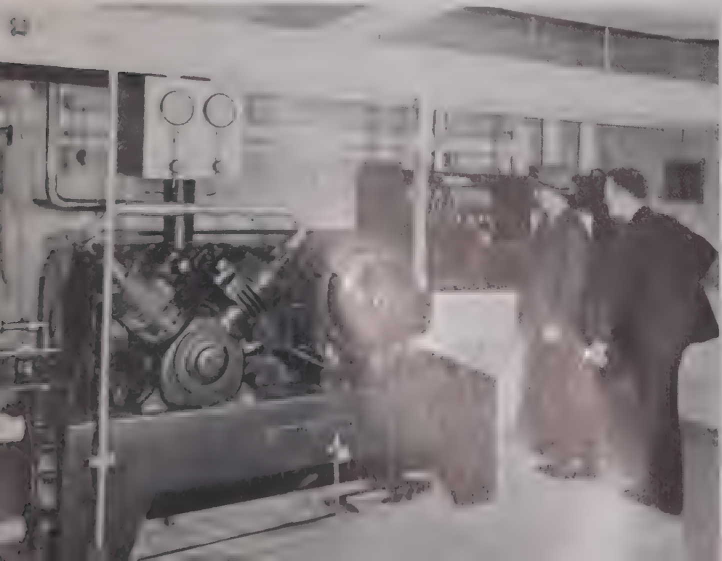


Fig. 4. Sectional view of valve plate designed for small clearance volume

Compressor equipment for cooling air conditioning; the unit is used to condition the library of a Washington summer school



With this type of design the sealed compressor has been greatly extended in size range, with one manufacturer producing units up to 100 hp in this construction. Sizes up to and including 5 hp are now fairly common.

Another important trend is that the true hermetically sealed compressor recently has been widely accepted in commercial refrigeration. As a result, its size range now extends through ¾ hp, where it previously was limited to ¼ hp. This acceptance has been brought about chiefly by the growth of the industry, which now supports a production, distribution, and service system that makes the stocking and replace-

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—ED.

ment of hermetically sealed compressors practical from the inventory point of view. Before the last war the emphasis was still on local field repair, and the use of hermetically sealed units in commercial refrigeration did not have wide acceptance.

In other lines of air-conditioning equipment, rapidly increasing costs of installation have accelerated the trend toward packaged air-conditioning units of all types. This in turn lends emphasis to the trend towards sealed compressors in sizes through 7½ hp because of the greater adaptability of the sealed compressor to packaged (or unitary) equipment, and also because of the somewhat greater freedom from service requirements.

One of the most important design problems in reciprocating compressors is presented by the valve design. The usual objectives are to obtain maximum effective area with the smallest possible clearance volume, and to accomplish this while maintaining a sturdy construction. These objectives tend to be incompatible, so that valve design is always a compromise. Substantial progress in valve design may be made by the adaptation of superior materials for the valves themselves, and work is currently in progress along these lines. As indicated in the section on Fundamental Problems, in Part I, the molecular weight of the refrigerant is a major factor, and any new refrigerant with a lighter molecular weight will have a strong influence on valve design and on resulting performance. A valve plate design for very low clearance volume is illustrated in **Fig. 4**.

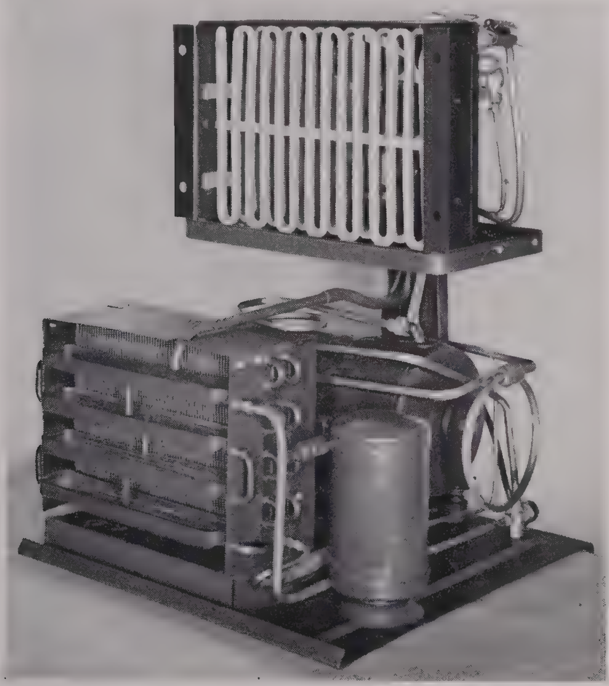
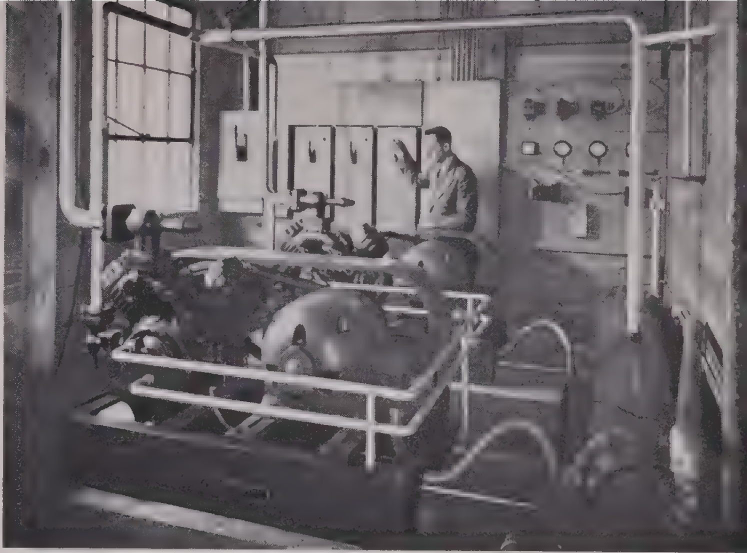


Fig. 5. A refrigerating machine using hermetically sealed compressor

The Lubrication Problem

The increasing use of reciprocating compressors for low-temperature work (0 F to −100 F) has brought with it some difficult problems in the development of satisfactory lubricants. These problems fortunately have been solved with reasonable success.



Motor-compressor units which provide refrigeration for storage rooms in an apple storage warehouse

One of the problems encountered in low-temperature work is the tendency toward selective solubility between the refrigerant and the various components of the oil. This is particularly true when a refrigerant is used which is not completely miscible with oil at all temperatures.

This selective solubility is, of course, aggravated with blended oils, and the result is that certain fractions of the oil will circulate, with others tending to accumulate in different parts of the system.

A further complication is introduced if the oil is synthetic and not completely saturated chemically. With such an oil, the high tempertures encountered in the region of the valve plate are apt to cause further polymerization, and the products of this polymerization are usually swept into the low side where they congeal and form a varnish-like substance on the surface and in the refrigerant control.

These problems are becoming well understood at least qualitatively, and quantitative test results are expected from research that is now in progress. At the present time oils and refrigerants are known well enough that very satisfactory results can be obtained in low-temperature work.

Unitary Refrigerating Machines

It was somewhat over fifteen years ago that the industry first began standardization of the assembly of components which is now known as the condensing unit. This assembly consists of a compressor, condenser, liquid receiver, motor, drive, assembly frame work, and the high-side controls.

Today, an extension of this idea is taking place in the smaller sizes of units. There is now a definite trend toward the use of complete refrigerating machines which one might consider essentially as condensing units plus the evaporators and low-side controls.

The advantage of such a unit, when a hermetically sealed compressor is used, is that it permits the removal

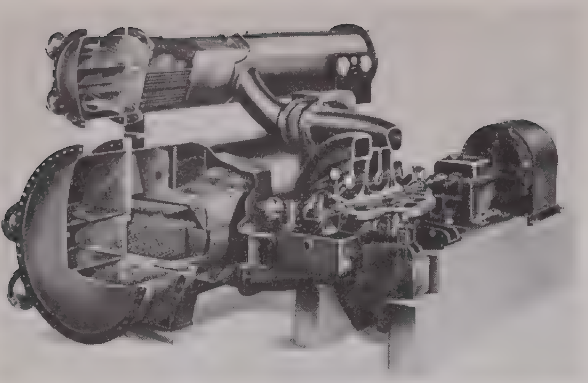


Fig. 6. Illustration of Worthington three-stage centrifugal compressor with condenser and water chiller

of a complete unit from a fixture for servicing. **Fig. 5** illustrates a unit of this type applied to a candy merchandiser.

Turbo Compressors

Centrifugal compressors are ideally suited to large capacities (200 hp and over) and are best adapted to refrigerants of high molecular weight and intermediate boiling points (such as Freon-11).

A gas of high molecular weight will result in a suitable relation between volume flow through the rotor and the pressure the rotor is able to produce with convenient geometrical proportions and a resulting high efficiency.

Recently, study has been given to the use of the axial-flow type of compressor for refrigerator service. This type of machine has an advantage in being susceptible of analysis, so that performance can be predicted with reasonable accuracy. Unfortunately, designs so far produced are not as flexible in speed-flow characteristics as are the centrifugals, and this undoubtedly has retarded their application, although recent research is improving this characteristic.

The centrifugal-type machine can be designed for a broad capacity range at fixed speed, and the range of conventional designs can be still further broadened by using multistage designs with backward-slope blades to reduce the effect of the diffuser (the most critical component so far as range is concerned).

Either type of turbo compressor (centrifugal or axial) has characteristics completely different from the reciprocating machine. For example, the turbo compressor at a given speed produces only a limited pressure and is not self-compensating in relation to condenser water temperature. Consequently the control problems are completely different from those of the reciprocating compressor.

From the application point of view the turbo compressor is interesting because of its adaptability to various refrigerants. For example, plants producing hydrocarbon products may, in some cases, use such products as refrigerants—a particularly advantageous system if the refrigerant itself is also the product that must be chilled and liquefied. Of similar interest is the use of turbo machinery in the liquefaction and fractional distillation of air for the production of liquid oxygen. This type of equipment will probably have increasing use in the production of low-cost oxygen

Fig. 6 shows a typical three-stage centrifugal compressor for refrigeration service.

Unitary Air-conditioning Equipment

Typical of this class of equipment is the store cooler a device that has proved increasingly popular over the last ten years. **Fig. 7** shows a typical product of this type in which the refrigerating machine and the air-circulating equipment, together with controls, are integrated in a single piece of equipment.

The air circuit includes a filter and a heating coil that can be used for tempering or heating, thus adding versatility. Another advantage of this particular unit is that the complete refrigerating machine is self-contained and separable from the structure and from the air-handling equipment. The trend in this class of equipment is to include larger sizes, probably including 20-hp sizes. This trend is stimulated by the high installation costs of separate components.

The Heat Pump

The idea of using a refrigerating machine to pump heat into a residence or other structure has been a subject of discussion and controversy ever since Lord Kelvin proposed its use in 1852. The first practical application to a residence appears to have been made in Scotland in 1930. Over the past 17 years numerous commercial installations have been made both in this country and abroad. At the present time many people

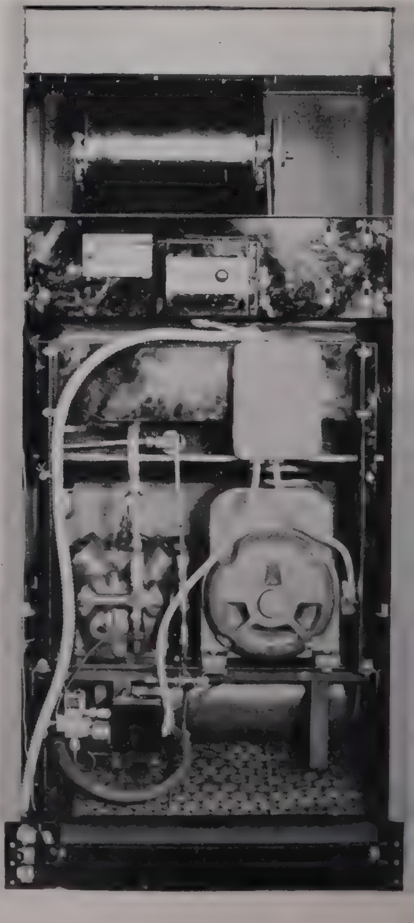


Fig. 7. A self-contained air conditioner of the store cooler type, front panel removed

elieve that the heat pump will be an acceptable piece f equipment for home air conditioning.

The first and most serious problem of the heat pump, rom the standpoint of residential use, is the matter of irst cost, which is greatly influenced by the balance etween winter heating requirements and summer ooling requirements.

A second problem occurs because the heat pump is ot capable of economically delivering heat at high emperatures. In fact, the temperature of delivery is ery appreciably lower than that commonly used in resent-day automatic heating equipment. This means hat a much greater air-delivery rate must be used to eliver the same quantity of heat and that the duct sizes nust be correspondingly larger. Also, these ducts must e designed to withstand the humid conditions of ummer air conditioning.

All of this means that architects, builders, and otential home owners will need to be educated, not nly to the advantages, but also to the limitations of he heat pump, and the architecture of our homes must e adapted to its use. While there is little doubt that his will take place over a period of years, it seems robable that the commercial growth of this application ill be slow.

On the other hand, heat pumps for commercial use in tores and similar commercial buildings will probably ind ready acceptance, particularly where summer air onditioning is a necessity and where the additional dvantage of tempered ventilation air for winter use is bvious (such as in a restaurant application). Furthernore, the balance between winter heating requirements nd summer cooling requirements in a commercial nstallation is usually much more favorable than that n a residence, so that the economy of first cost is more avorable.

Among the technical problems of the heat pump, the eed for automatic capacity modulation of the comressor and for a suitable and automatic balancing of notor power against compressor displacement is ndoubtedly the outstanding problem—one which is urrently being given close attention.

erchandisers

The art of merchandising is continually growing, nd it is being aided by technological, mechanical, and isual aids. This has caused a substantial growth in he market for refrigerated merchandisers. This growth s also supported by the growth in the sale of chilled everages and by the phenomenal growth of the rozen-food business.

All of these factors have brought about a substantial hange in the size and complexity of the market for efrigerated merchandisers of all kinds. These include everage coolers, air-conditioned display cases for andy, and low-temperature display cases for frozen oods as the outstanding examples.

Fig. 8 shows a typical product in this class that is eing built for a well-known candy manufacturer. This ype of equipment will increasingly use the small, completely self-contained hermetically sealed refrigerating machine. The designing of this class of equipment, although still concerned with the well-known technical problems of external vapor seals, more importantly includes the artistic problems of the industrial designer.

Water Coolers

Our habit of drinking ice water has, no doubt, had much to do with the wide acceptance of the drinking water cooler shown in **Fig. 9**. Its reliability, sanitary features, and the convenience of having a continuous supply of refreshingly cool water has continually improved its acceptance over the last fifteen years.

The technical problems in this class of equipment are, of course, the usual problems of refrigeration, plus problems of control to avoid accidental freezing, and the chemical and sanitation problems associated with

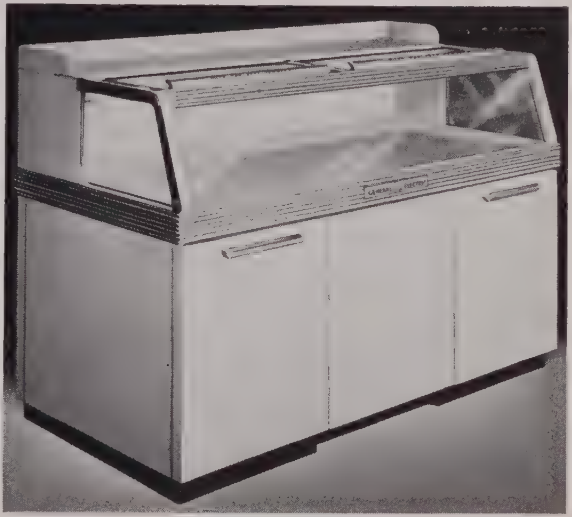


Fig. 8. Refrigerated display case designed for merchandising candy

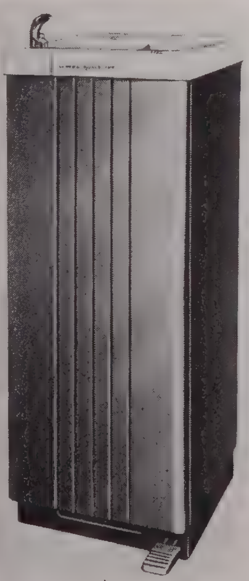


Fig. 9. A modern water cooler with self-contained refrigerating system

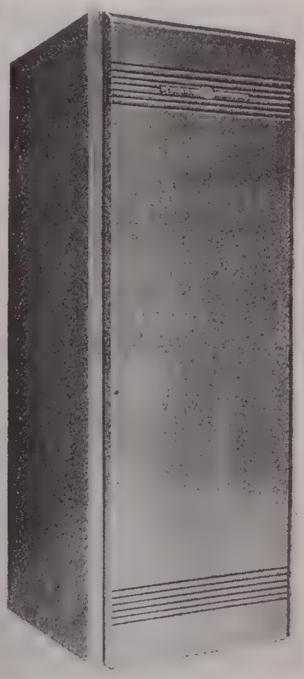


Fig. 10. An oil-fired warm-air furnace of modern design

supplying drinking water so that it will meet all sanitation and code requirements.

The present trend in these equipments is definitely toward the use of hermetically sealed compressors, and the future will undoubtedly see a trend toward smaller size and more compact arrangement.

Automatic Heating Equipment

The trend in automatic heating equipment is also toward packaged construction, with small sizes and compact arrangements matching the present trends in housing construction. A typical small oil-fired warm-air conditioner is shown in **Fig. 10**. This particular equipment can be installed in a closet with only two inches of clearance.

A probable trend is that of manufacturing a complete utility core for a house in which the heating plant, bathroom, laundry facilities, and kitchen facilities are all assembled as a complete working unit. This core is then shipped to the house location, and the structure of the house is built around it. Some of these utility cores have been manufactured and used in house construction during the last two years. Another trend in heating is that of providing a continuous (or modulated) heat flow in preference to the prevalent on-off type of operation.

A trend which is not particularly welcome is that toward greater variation in the quality and type of liquid and gaseous fuels. From the equipment designer's point of view it would be much better to have standardized fuels, but the growth and complexity of the fuel industry is such that the industry must find ways of using greater varieties of fuel, and equipment designs are being modified to accommodate this range.

Equipment for All-year Home Conditioning

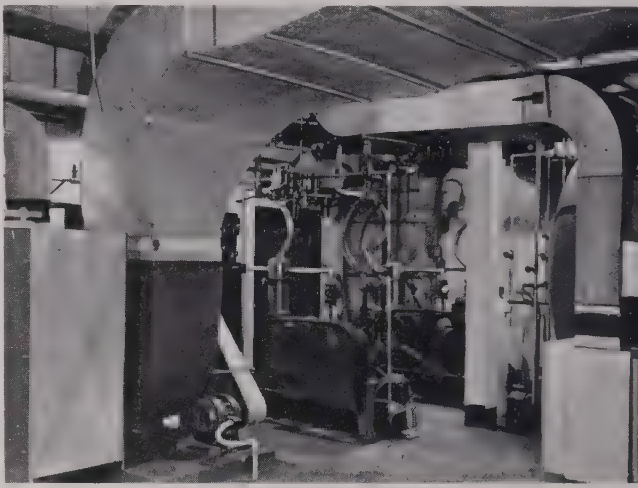
The equipment and architectural requirements for year 'round air conditioning of the home have not yet been crystallized. This may seem strange, but it must be kept in mind that our national economy has not yet reached the point where summer air conditioning of the home is considered as necessary a convenience as, for example, the bathtub or the heating equipment.

As mentioned in the section on Heat Pumps, equipment design is not the only problem. The architectural problem is just as great and perhaps more difficult. Certainly it will be a period of years before the typical small home is designed with summer air conditioning in mind. Until this is done, the application of summer air conditioning to the home will face difficult structural and economic problems. Without attempting to consider all of the technical aspects of this problem, there is given in the following a brief analysis of some of the different methods by which home air conditioning can be accomplished under various circumstances.

Room Air Conditioners. The room air conditioner is a self-contained device which can be plugged into an electric circuit and which is capable of cooling a single room of reasonable size. It is suitable for office and bedroom application.

Mechanical and Chemical Dryers. Along the Eastern an Southern seaboards, comfort can be considerably er hanced if the air is merely dried, particularly if it ca be dried by a mechanical refrigerator so that the dry bulb temperature does not increase. Chemical dryer can do an effective job of removing moisture, but must be recognized that they all involve constan enthalpy processes which result in an increase in dry bulb temperature unless other means are used for cooling

The Desert Cooler. In very hot, dry climates the deser cooler currently has wide acceptance. This is simply water-soaked core through which air is blown to give decrease in dry-bulb temperature at the expense of a increase in humidity. The enthalpy does not change.



A reverse-cycle heating and cooling system, showing two 20-hp refrigera compressors and central-plant conditioners

Furnace and Store Cooler. The combination of a piec of automatic heating equipment and a conventiona store cooler can be used to give year 'round home a conditioning. There are difficulties of application unles the duct system is designed for the application. Als store coolers often require too much head room fo ordinary basements.

Furnace and Refrigerator. The use of a warm-air fur nace together with a condensing unit and a refrigeratin coil mounted in the main duct is finding some accept ance. It is particularly applicable where the furnac capacity is relatively large, and where the furnace fa is therefore adequate to give the required air flow fo summer air conditioning. In climates where the heatin requirement is moderate and the summer air condition ing requirement is high, the furnace blower may not b adequate for the summer air conditioning load. In suc cases, an auxiliary blower is desirable.

Absorption System with Steam Heat. If steam heating i used in the winter, the steam from the boiler can b used to operate an absorption system. Equipment o this type is being manufactured at the present time One of the limitations of any absorption system i caused by its high heat-rejection rate which require either a large amount of water or relatively large ai heat-transfer surfaces.

Electric Heat Pump. This is the year ’round air-onditioning system of the future and has been condered previously.

It appears that there is a definite need for a prootional effort among equipment builders, home uilders, and architects to disseminate a broader and ore accurate knowledge of the architectural requireents and equipment requirements for year ’round ome air conditioning. The entire industry and also the sers of the equipment would undoubtedly benefit from program of this type.

dustry and Economic Trends

The field of air conditioning and refrigeration is one at appears to be marked for a substantial growth uring the next ten years.

In the field of automatic heating the growth during ie postwar period has been remarkable and confirms ie expected trend towards automatic heating equipent. In the five years 1945–51, the Oil Heat Institute xpects home owners to purchase four and one-half illion oil burners of all kinds. A number of surveys ave been made which indicate a strong preference on ie part of the consumer for automatic heat. This reference is much stronger now than it was before the ar. Moreover, the potential market is still large, as dicated by the fact that slightly more than 50 per cent the occupied homes in 1945 had no central heating.

The frozen-food business supports a great deal of tivity in refrigeration, and while this business is still nall and growing, it is larger than most people realize. or example, there are about 12 cubic feet of public and rivate cold-storage warehouse space for each family in ie United States, and surprising quantities of frozen od are warehoused in this space at any one time. An verage storage of 700 million pounds of meat, 100 illion pounds of poultry, and 150 million pounds of ozen fruit—these are typical figures indicating the nount of frozen-food storage.

The growth of the frozen-food industry can be observed directly by the number of frozen-food display cases in retail stores. It is also indicated by the fact that locker plants grew in number from 250 in 1933 to some 8000 in 1947.

Air conditioning is also a growing industry. It has been estimated that some thirty different lines of business, including chemicals, textiles, foods, printing, and tobacco, find air conditioning an essential aid. The growth of the industry is indicated by the fact that up to 1948, 1200 hotels, out of an estimated total of 25,000, had been air conditioned. An estimate published during 1947 by Michael-Cather, Inc. gave a figure of 100 million dollars as the annual market for the air conditioning of industrial and commercial buildings.

A great many more statistics could be cited. In general they indicate that, although the air-conditioning industry may be small when compared to some of the mammoth industries, it nevertheless has reached the stage of being a very lusty infant with prospects of substantial growth in the future.

A point of particular interest to everyone who believes in the free enterprise system is the complementary manner in which large business and small business support each other in this field. For example, the Air Conditioning Department of the General Electric Company alone has some hundreds of dealers and distributors, each of which is a small business depending upon a large company for its flow of products. Conversely, the large company is equally dependent upon these small businessmen for providing the channels of marketing and for providing distribution and maintenance services in local areas to ultimate users of this class of equipment. Altogether, the arrangement presents a picture of finely interwoven interests extending a pattern all over the continental United States and enmeshing the personal interests of individual users, small businessmen, and large manufacturers in a common effort to improve the standard of living.

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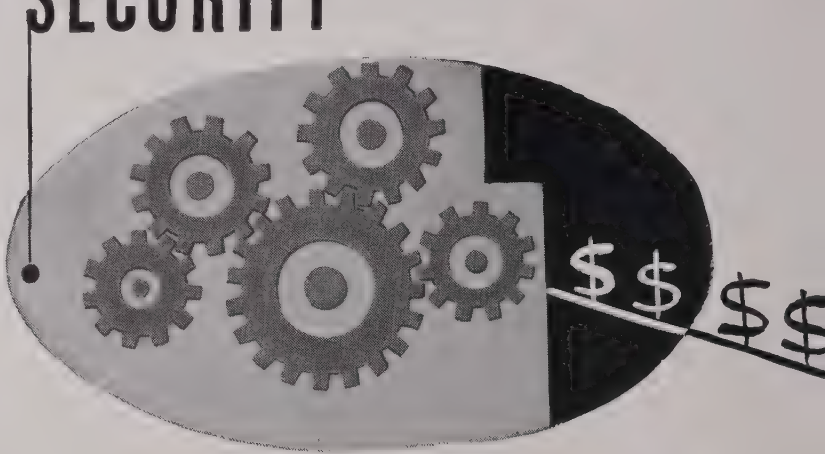

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Security for the nation . . . because every Bond dollar that is built up in the Treasury is used to retire a dollar of the national debt that is potentially inflationary, and because every Bond held means fewer dollars to go to market to bid up prices on scarce goods.

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HIGH LIGHTS AND SIDE LIGHTS

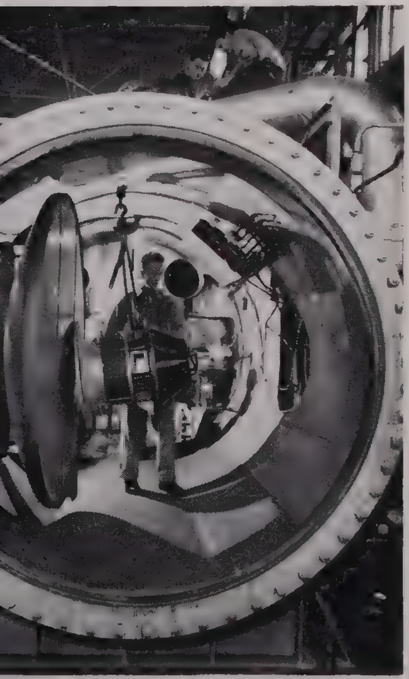
Torque Meter Helps Test Fans

A 250-lb-ft torque meter plays an imortant part in the testing of large fans a wind tunnel at the Jeffrey Manucturing Company, Columbus (O.), here mine fans and other industrial rocessing and handling equipment are anufactured. Use of the torque meter elps to reduce the time required to test e fans to one quarter of one per cent of e original period.

Normally, such a torque measurement ould be made by cradling the driving otor. In this case, however, the 75-hp riving motor is too large to be placed ose to the fan in the air stream. In addion, the long shaft needed to connect the otor and fan would have to be supported y intermediate bearings, and the resultg losses would be sufficient to cause the rque measurement at the motor to be roneous.

Therefore the torque meter is installed ith a small 3¾-in.-diameter shaft unit cated in the cowling of the fan. The rque meter determines, within plus or inus one per cent of full scale, the amount torque supplied by the large motor to e fan under test. The torque readings e indicated at an adjacent control desk.

Laboratory Testing



scale-model jet-engine compressor being ounted prior to laboratory testing for altitudes to 70,000 ft and temperatures from 70 below ro F to 150 above. Another of the many laboray facilities at this center for the development, ting, and production of aircraft jet engines is strated on the cover of this issue

New Tone and Transcription Arms

A new tone arm, equipped with the variable reluctance cartridge, for playback of 10- and 12-inch records, and a new transcription arm for professional use, have been developed.

The new transcription arm is adjustable for stylus pressure and has an easy-to-read scale calibrated in grams and ounces

Designed specifically as a companion unit for the variable reluctance cartridge, the new tone arm provides the best compromise between minimum tracking error and over-all dimensions. It is balanced at the factory, giving 1-oz stylus pressure, yet may be adjusted to any stylus pressure.

The new arm may be used with any record player without an automatic changer. Each is supplied with a tone-arm rest, mounting template, and a 24-in. special cotton-covered shielded lead.

The new transcription arm is designed for use by broadcasters, sound laboratories, recording studios, and wired music services. It features simple installation on popular turntables, no arm resonances in audio range, low mass, and low arm friction. It is completely adjustable for stylus pressure, and has an easy-to-read scale, calibrated in grams and ounces.

New Technique in Brazing of Stainless-steel Parts

The coming era of jet engines and rockets is being accelerated by the development of a new brazing technique which makes possible the joining of precision, high-temperature stainless-steel parts.

Furnace-brazing, the uniting of several metal parts by melting a metal such as copper into the joints, has been extremely difficult in the heat-resistant alloys containing chromium necessary in the construction of jet engines and rockets. In the past, such attempts have resulted in the oxidation of the chromium. Or, when a chemical flux for preventing oxidation was used, the cost of removing flux deposits afterwards has been excessive and time-consuming.

The new process succeeds with tricky stainless steels by brazing them in a hydrogen atmosphere purer than any previously used. When moisture or oxygen is present in a furnace atmosphere without flux, the chromium will oxidize.

The parts to be brazed are sealed in a box, which is then filled with pure hydrogen. As in regular furnace-brazing operations, copper is placed adjacent to the joints to be bonded, so that when molten it will creep into the joints. The sealed box is introduced into the heating chamber of an electric furnace for twenty minutes to an hour. It is then allowed to cool. Before the box is removed from the cooling chamber, the hydrogen, which is explosive when mixed with air, is exhausted and replaced by nitrogen, which is not.

The furnace-brazing of assemblies by this new technique is sometimes used as an alternative to making parts by the more common methods of forging, casting, machining from solid stock, or even other fabricating methods such as torch-brazing. Machining time and waste metals are often reduced in such instances. Intricate assemblies sometimes can be fabricated which otherwise could not be made any other way to obtain the quality and results needed. The perfectly clean, bright surfaces resulting from furnace-brazing are a particular advantage.

Square-wave Generator

Cabinet and control board of the new square wave generator

School and college research projects and scientific laboratories will soon be making use of the new square-wave generator which has recently been made available.

The new precision-type instrument features six overlapping frequency ranges, giving continuous coverage from 5 to 125,000 cycles. It delivers a rectangular-wave output voltage with a 25 per cent negative pulse, and a rise time for the leading edge of 0.3 microsecond.

A self-contained power supply is electronically controlled to provide stable output under conditions of commercial line-voltage fluctuation. The output can be synchronized to an external source if desired.

The device is supplied in a cabinet, but can be removed for mounting in a standard 19-inch relay rack. It weighs 44 lb.

(Continued on next page)

Six-year Creep Test

A slender steel rod, apparently little the worse for its experience, emerged from a laboratory torture chamber recently after undergoing a temperature of 1000 F and a stress of 6000 lb for 50,000 hr.

"Item 1113," as the 20- by ½-in. test specimen was known in the laboratory, had endured the heat and tension for about six years.

The prolonged ordeal called the "creep test" enables engineers to compute the amount of "creep," or change in the sample's original dimensions, that has taken place during the period.

The object is to discover how a given alloy will behave as a turbine part, and the best way to find out is to subject a sample to the heat and stress it would experience were it in a hot, spinning machine. If, in the creep test, a sample is distorted in a short time, that alloy is rejected for turbine construction, for too much creep in its parts would soon put a machine out of commission.

This particular sample had an especially long ordeal because the laboratory is particularly interested in the properties of this alloy steel for use in turbines. The usual creep test lasts only about three months. Item 1113, however, is not the grand-daddy of them all, for four venerable old pieces of nickel-chromium ste did an all-time high stretch of 100,0 hr, or twice as much, from 1931 throug 1942. Laboratory engineers doubt th the mark, a world's record, will ever broken.

Gas Turbine for a Utility

The first gas turbine for an electric utility in this country—part of a 3500-k gas-turbine-generator set—is under co struction for the Oklahoma Gas ar Electric Company. A duplicate of t 4800-hp locomotive gas turbine current undergoing tests and first publicly a nounced in March before executives American railroads, the gas-fired unit w be installed at Oklahoma City.

The new unit will be operated natural gas, which is available in abu dance in the area. Maintenance of t power plant is expected to be low becau the gas turbine has only two major movi parts. The unit has been designed f maximum accessibility during maint nance and inspection periods, and elemen which might normally require maint nance are easily replaceable.

The gas turbine will be geared to conventional 3600-rpm generator. N water will be required in the operation the plant, except a small quantity f cooling the bearing lubricating oil ar the a-c generator.

Measuring Magnetic Properties

A new device has been developed whi can rapidly and accurately measure se eral magnetic properties of a small samp of metal, thus enabling engineers to pr dict accurately the magnetic performan of the same metal in finished electric equipment.

Sensitive enough to record minu quality variations between samples of t same metal, the instrument tests thin-ga magnetic metals for energy losses wh subjected to magnetization and also mea ures the magnetic permeability, or willin ness to be magnetized. Using data fro the testing device, engineers can pred properties of magnetic materials f motors, generators, transformers, a other equipment.

The new device makes possible for t first time rapid tests of several properti Previous test equipment could test or one property and involved complex oper tions by trained technicians.

The new equipment can be operated a relatively untrained person; should inexperienced operator turn the wro sequence of dials on the control pan none of the delicate measuring instrumen would be injured.

Known technically as the a-c perme bility and core-loss equipment, a numb of the devices are already in use in t steel and electrical industries.

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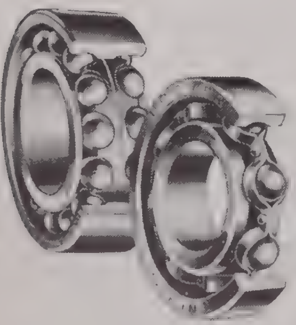

There are few people who can ring the bell at the country fair. This is a task that takes more than strength . . . it takes smoothness, precision and timing.

There is only one ball bearing that has honed raceways . . . the Hoover Ball Bearing. The extra precision and smoothness that result from honing increase the life span of Hoover Ball Bearings. Due to honing, Hoover Ball Bearings have closer race curvatures . . . greater area of ball-supporting contact . . . and 30% more load carrying capacity. You get these advantages plus unbelievable quietness with Hoover Honed Raceways.

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e instrument consists of a heavy base
l post, on which the microscope bracket
vertically adjustable by spiral rack and
ion. An additional vertical adjustment
he microscope tube within the bracket is
vided for greater capacity, particularly
en handling work between centers. The
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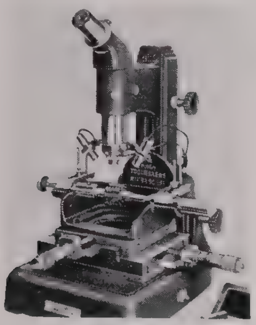
gnification for the image of the work.
e standard reticule in the eyepiece con-
ns a 90-deg hairline cross and a 60-deg
gle cross for thread measurements. The



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tems, kitchen equipment, and wire
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ed thickness of metal. The welder is
closed in a noncorrodible cast-aluminum
sing with an aluminum handle for easy
rying. The protruding copper arms are
ailable in three lengths—6, 12, and 18 in.
and special alloy tips can be obtained in

assortment of shapes. Each unit has a
con steel and copper transformer wound
th spun-glass insulated magnet wire.—
eyhound A.C. Arc Welder Corp., 606
hnson Ave., Brooklyn 6, N. Y.

Fan Cooler

A new industrial type circulator, known as Model M-351 Man Cooler, designed specifically for use in factories and commercial plants where mass movement of air is essential to employee comfort and efficiency.

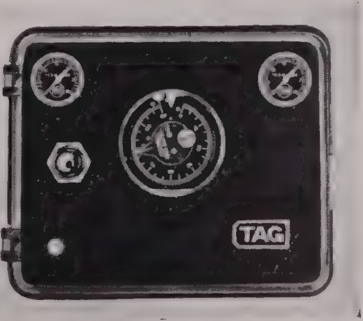
This cooler has an extra-large custom-built G-E motor which is dynamically balanced to eliminate vibration. This ⅙-hp capacitor-type motor has two speeds—1050 and 730 rpm—with a locked-rotor amperage on high speed of 7 amp and low speed of 1¾ amp.

Construction is of 18-gage expanded metal on the sides with 1½ in. by 16-gage expanded metal front and rear guard. An easy-to-clean removable safety guard provides over-all protection against the common hazard of workers getting their fingers caught in the propeller. Provision is also made to operate the cooler by remote control, if so desired.—*Fresh'nd-Aire Co., Chicago, Ill.*

Timer

A new type TAG time-schedule controller can be synchronized with any system of air-operated semiautomatic temperature and pressure control now in use to make the process fully automatic.

To begin the process, the operator presses the starter push button on the timer; then a signal light above the button flashes on to indicate that the process is under way.



By means of an adjustable cam, timing begins immediately, or, if desired, when the temperature has reached the processing point. This temperature is maintained for any predetermined length of time. All valves—steam, air, drain, overflow, and cooling water—are operated as required by each individual process, eliminating manual adjustments. At the completion of the process and the cooling period, the signal light is extinguished, visibly indicating that the process cycle has been completed.—*C. J. Tagliabue Corp., 614 Frelinghuysen Ave., Newark 5, New Jersey.*

Climbers

A new set of matched right-and-left Pole Master climbers provide more comfort to linemen because a scientifically designed extra-wide stirrup gives greater arch support. Leg irons are constructed with taper and are flexible to eliminate chafing of ankles and calves. The shank is offset to bring gaff in proper line with leg bone. The wrought-iron triangular-shaped ring for the ankle strap gives full support to the width of the strap, minimizing wear and assuring long strap life. These climbers are forged from special analysis alloy-steel and weigh 2⅞ lb per pair.—*Mathias Klein & Sons, 3200 N. Belmont Ave., Chicago 18, Ill.*

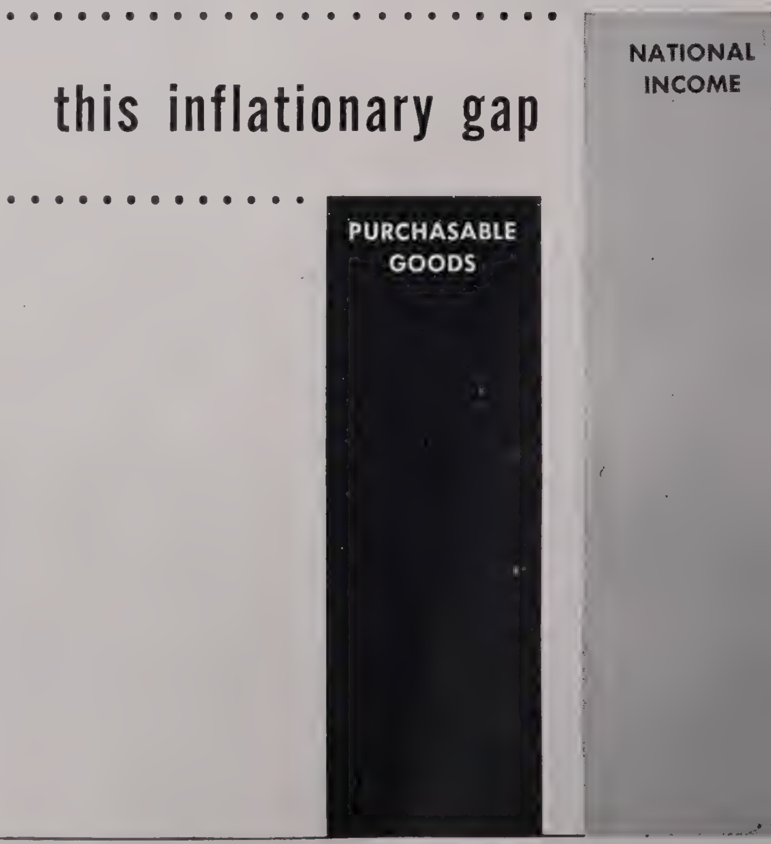
Portable Potentiometer

A new portable potentiometer for precise measurements of very low voltages is designed for checking temperature-measurement instruments and for the testing of rotating machines, ovens, furnaces, oil-burners, steam-driven equipment, and air-conditioning units.

The unit includes a galvanometer, standard cell, working batteries, and rheostats for adjusting the current through the potentiometer circuit. The galvanometer has a built-in transformer for operating the lamp from 115-volt a-c supply lines; or, if field conditions dictate, the lamp can be operated from four No. 6 dry cells. Convenient keys are provided to permit rapid readings. Contacts are enclosed. This potentiometer has two ranges: 0 to 60 and 0 to 6 mv.—*Meter and Instrument Division, General Electric Co., West Lynn, Mass.*

(Continued on next right-hand page)

HOW you and your employees can reduce this inflationary gap



With proper guidance from top management, the nation's workers can powerfully attack inflation at its source.

One way, of course, is by increasing production. But production of most goods already has been pushed to maximum! The other approach is to reduce the volume of dollars that can be used to bid up prices on scarce goods.

There's no more effective tool for this job than the Payroll Savings Plan for the regular purchase of U. S. Security Bonds. Via this plan, 5.5 million wage earners are investing over 8% of their pay—over 100 million dollars per month—in Bonds.

What Is the Status of the Plan in Your Company?

In companies where top management backs the Plan, 35% to 50% of the employees participate, and the average total Bondholding is $1200 per family. If these figures are above those for your employees, it is apparent that the Plan needs reinvigoration by your personal sponsorship.

Benefits Accrue to the Nation and to Your Company

Every Bond dollar that is built up in the Treasury is used to retire a dollar of the national debt that is potentially inflationary. Every Bond held means fewer dollars to go to market to bid up prices on scarce goods. In addition, dollars invested in Bonds are building future purchasing power. All these factors contribute to the security of the national economy—including your business.

Bonds build security for individuals, because every $3 invested pay $4 at maturity.

Moreover, in 19,000 companies operating the Payroll Savings Plan, employees have proved to be more contented. Worker production has increased, absenteeism has decreased—even accidents have been fewer!

Management's Role Is Vital

Even with all its benefits, the Payroll Savings Plan requires sponsorship by top management to keep employees *aware* of the benefits. That's why the Treasury Department has prepared a kit of materials especially for you to distribute among specific key personnel. Be sure to get and use your kit—for the security of your company and your country!

For any help you want, call on your Treasury Department's State Director, Savings Bonds Division.

The Treasury Department acknowledges with appreciation the publication of this message by

GENERAL ELECTRIC REVIEW

This is an official U. S. Treasury advertisement prepared under the auspices of the Treasury Department and the Advertising Coun

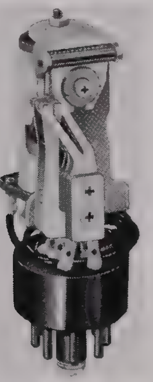
Welding Holder

A new ejector-type light-duty resistance-
elding holder of leakproof design. The
lder is so arranged that the water circuit
rces water against the head of the elec-
ode tip regardless of length, and the water
cuit is sealed to prevent leakage, eliminat-
g a rust problem on the work.

Tip removal is simplified and tip damage
nimized by the use of an ejector plug.
e complete holder barrel is made of an
oy having high electrical conductivity
d physical strength.—*P. R. Mallory &*
., Inc., Indianapolis 6, Ind.

Relay

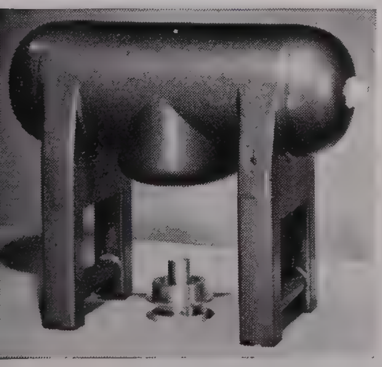
A new lightweight, plug-in-type, d-c
ay, known as Type "J," for installation
ere quick removal and easy replacement
e desirable. Some characteristics of the
ay include independent twin contacts,



gh current-carrying capacity, large arma-
re-bearing area, efficient magnetic struc-
re, high operating speed, and large con-
ct-spring pileups. The relay is supplied
th standard octal base plug, the over-all
ngth being 3⅝ in.—*C. P. Clare & Co.,*
19 West Sunnyside Ave., Chicago 30, Ill.

Radioactivity Shield

A new lead shield, Model 3030, permits
e safe study of radioactive materials.
is shield consists of a lead cylinder of
4-in. wall thickness, with a center space
accommodating glass Geiger counters,
in. in diameter and 8½ in. long. The

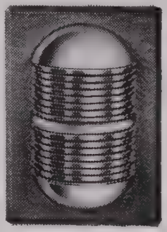


ield weighs 96 lb and has been designed
th two handles to permit moving it
ound.

This shield is complete with a cable con-
ctor on one end and a built-in sample
lder which provides easily reproducible
ometries. It can be easily dismantled and
e liner removed for decontamination
rubbing.—*Instrument Development Labo-*
tories, 229 West Erie St., Chicago 10, Ill.

Pilot Light

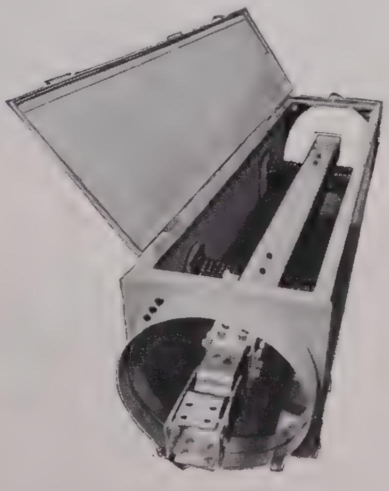
New electric utility colored pilot lights designed for signal applications, warning, decoration, and general illumination. These lights are available in one type of eight-prism lens to four separate lenses or more, mounted on a plate 4½ in. wide, the depth varying with the number of lenses. The unbreakable plastic lens is offered in a choice of five colors.



The snap-on cover-plate construction facilitates removal when lamp change is needed because the use of tools is not required. Units can be mounted in standard switch outlet boxes, with plaster rings. Plaskon mounting plates are made in antique ivory, silver, bronze, copper, or gold hammertone finish.—*Cannon Electric Development Co., 3209 Humboldt St., Los Angeles 31, Calif.*

Enclosed Bus Run

A new aluminum-enclosed isolated-phase bus run for safely interconnecting generators, transformers, and switchgear equipments. The equipment, tested and assembled to meet AIEE and NEMA standards, is for 15-kv applications in current ratings of 1200, 2000, 3000, 4000, and 5000 amp and has a basic impulse level of 110 kv. Each phase of the bus run has a single aluminum sheet shaped to form three sides of the housing. The fourth side, which is hinged, forms a gasketed and clamped cover.



Sections of the bus are shipped completely assembled, and end bells of adjacent sections are connected by split aluminum bands having gasketed mating flanges. In addition to making a tight joint, the gasket arrangement breaks up circulating current paths.—*General Electric Co., Switchgear Divisions, Philadelphia, Pa.*

Wire Finish

A new slippery finish for electrical wire makes wire pull more easily through sharp bends in conduit. The slippery surface is produced by a new wax coating on the insulation which enables the wire to slide with but one third to one half the amount of pulling formerly required.

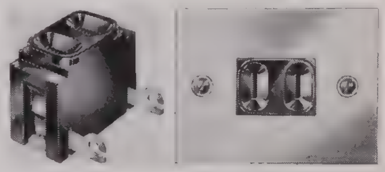
The wax is used on Laytex wire, widely employed in homes and commercial buildings. It is expected to speed up the installation of electrical equipment, particularly in locations difficult of access and where sharp-angle conduit is employed in the electrical system.—*United States Rubber Co., Rockefeller Center, New York, N. Y.*

Heater

A built-in electric wall heater for use when additional instantaneous heat is desired operates on the radiant-convection principle. The heater is rated at 1320 watts 115 volts a-c or d-c and delivers 4507 Btu per hour. Over-all, the heater is approximately 17 in. by 13 in. by 4¾ in. and, when mounted in the wall, the removable steel guard projects only ⅝ in. Exposed surfaces are finished in gray; the reflector is made of polished corrugated aluminum; and the two heating elements are of Nichrome wire. —*General Electric Co., Appliance and Merchandise Dept., Bridgeport, Conn.*

Receptacle

A new type of receptacle designed for permanent soldered connections, with phosphor-bronze contact springs and easily adapted to all types of electrical appliances.



Each contact has two integral blades; a short one having a stiff action, the other a longer blade sufficiently flexible to permit easy entry.

As the longer blade is deflected by the plug prong, it makes contact with the shorter blade which, because of its short length, provides the stiffness and high pressure required for good electrical contact at all times. Neither blade can be overstressed nor can the plug prongs engage the wrong side of the blades.—*G-M Laboratories, Inc., 4300 N. Knox Ave., Chicago, Ill.*

Fluorescent Plastic

A new fluorescent form of acrylic plastic, called Daylight Fluorecsent Plexiglas, for signs with self-illuminating lettering, for decorative panels with edges and surface designs that glow brightly under their own power, and for dials, pointers, and nameplates.

The phenomenon of the built-in edge-lighting effect is caused by millions of fluorescent dye particles with which the plastic is impregnated during manufacture. The particles of dye, when struck by light rays entering the fluorescent sheet, reflect the light in all directions. Most of the reflected rays are trapped within the polished sheet and travel through it by repeated interior-surface reflections to the edges, where they escape in a high concentration of fluorescent light. If the edges are covered with a reflecting material such as foil, white lacquer, or aluminum, the brilliance of surface designs will be intensified.—*Rohm & Haas Co., Philadelphia, Pa.*

radio
interference filtering with C-D Quietones*
An Invitation from C-D
WORLD'S MOST ADVANCED RADIO "NOISE-PROOFING" LABORATORY IS AT YOUR SERVICE
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We have designed—and have available—many types of C-D Quietones which are equally effective on both Radio and video bands. They meet every requirement of manufacturers' cost and production schedules. One of these standard types may remove your product from the list of Radio interference generators. If not, we're ready and waiting—with a modern and complete laboratory and experienced engineers—to design and build a Quietone to meet your specific needs. Your inquiry is cordially invited. Cornell-Dubilier Electric Corporation, Dept. L-7 South Plainfield, New Jersey. Other large plants in New Bedford, Worcester and Brookline, Massachusetts, and Providence, Rhode Island.

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* Reg. U.S. Pat. Off.

TRADE LITERATURE

ll Bearings—Information on extra-small l bearings has been assembled in this bul- n which includes data on radial, angular- ıtact (radial thrust), self-aligning radial, l pivot types. Consideration is also given nonmagnetic and stainless steel bearings, erances, housing and mounting methods l fits, speed and life, and bearing load. ht pages. Technical Bulletin No. 48.—*w Hampshire Ball Bearings, Inc., Peter- ough 1, N. H.*

nstruction Materials for Corrosion Fluids ntended as a technical aid for designers l engineers, this bulletin provides detailed ommendations on construction materials nearly 400 different corrosive liquids l gases for use with Flowrotor instru- nts. The recommendations are listed ler three headings: end fittings; metering ıts; and packing materials. Bulletin No. —*Fischer and Porter Co., Dept. 7F-L, tboro, Pa.*

esel-electrics—A brief description of die- electric locomotives and their perform- e in several different industries is given this bulletin titled "Switch to Diesel- trics and Save." Listed in table form is "pulling power" of the various sizes diesel-electrics, and appearing on the k page are brief specifications. Eight es. GEA-4909.—*General Electric Co., paratus Dept., Schenectady 5, N. Y.*

acture of Metals—Published in booklet m, this report to the Bureau of Ships vides a means for engineers and de- ners to approach the problem of fracture l represents a compilation of the present owledge of the laws and fundamental chanism of fracture. The booklet is di- ed into two parts. Part I includes the ginal survey of the literature and an lysis of the theories of fracture and plications of principles; Part II is a supplement in that it uses the framework established in Part I to classify new developments in the theories of fracture and plastic flow. Priced at one dollar. Eighty-four pages. Entitled "Fracture of Metals." —*American Welding Society Headquarters, 33 West 39th St., New York 18, N. Y.*

Lightning Protection—Consideration is given to the role played by lightning arresters in radio, police alarm, fire alarm, railroad signal, telephone, and telegraph circuits, with particular reference to the use of rare-gas arresters. Special sections are given to entrance panels, terminal strips, and potheads. Sixteen pages. Catalog 48-A. —*L. S. Brach Manufacturing Corp., 200 Central Ave., Newark, N. J.*

Mechanical Differentials—A descriptive and illustrative folder simply and clearly demonstrating the operating principle of these high-precision calculating mechanisms. They are of particular interest to manufacturers and designers requiring machine components to combine algebraically two mechanical quantities measured by angular displacement. Four pages.—*Arma Corporation, 254 36th St., Brooklyn 32, N. Y.*

Mechanical-drive Turbines—No. 1 in a series of bulletins designed to aid in the selection of turbines and their proper application is entitled "When to Use Mechanical-drive Turbines." This publication outlines primary and secondary advantages of turbine drives, the various types, and their over-all economy. Sixteen pages. GEA-4986. No. 2 in this series of bulletins presents detailed information concerning ratings, steam condition, special features, and accessories. Twelve pages. Entitled "Factors You Should Consider When Specifying Mechanical-drive Turbines." GEA-5028.—*General Electric Co., Apparatus Dept., Schenectady 5, N. Y.*

Relays—Resonant relays that make remote control possible by radio or carrier current through frequency discrimination are described and illustrated in this bulletin which is accompanied by a price list and ordering specification sheet. Circuit diagrams and operating curves are also presented. Four pages. Catalog No. 116A—*Stevens-Arnold Co., 22 Elkins St., South Boston 27, Mass.*

Resistance Welders—In this well-illustrated booklet, basic recommendations are given which apply to the selection of welding equipment insofar as electrical power supply is involved. Tri-phase welders of the power-reduction type are recommended for use if the power supply is inadequate, and the resultant advantages are given. Eight pages. Bulletin 10-813.—*Taylor-Winfield Corp., Warren, Ohio.*

Templates—This catalog is a compilation of the various Time-Saver templates for engineers, designers, draftsmen, and architects. Each type of template is pictured, designated by name and number, briefly described, and individually priced. Four pages; Catalog No. 48.—*Rapidesign, Inc., P.O. Box 592, Glendale, Calif.*

Time-delay Relays—These relays of the motor-driven type are for operation on alternating current. The folder illustrates and describes their operation under a wide range of conditions. Circuit diagrams for each of these conditions supplement the text. Four pages. Bulletin 362.—*Ward Leonard Electric Co., Mount Vernon, N. Y.*

Time Switch—The operation, construction, and advantages of the Handy time switch is comprehensively presented in this bulletin. In addition to the wiring and dimensional diagrams, illustrations show four of the many suggested uses for this device. Prices and rating data are given. Two pages. GEA-4874.—*General Electric Company, Apparatus Dept., Schenectady 5, N. Y.*

BOOK REVIEWS

(Available books may be purchased through the General Electric Review for domestic delivery; none sent on approval.)

crowave Mixers

bert V. Pound, with chapter by Eric rand—McGraw-Hill Book Co., Inc., w York. 1948. 393 pp. $5.50.

This particular book is Volume 16 in the I.T. Radiation Laboratory Series, which nsists of twenty-eight volumes. There are ny cross-references to the other volumes the series. However, these references are essential to the understanding of the terial presented.

The preface modestly states that the esent volume describes the design of the ious microwave circuits that have been ed as mixers in the microwave region at Radiation Laboratory. The book begins h an introductory chapter describing ious types of mixers and their associated lio-frequency components. Further chap- s deal with crystal-rectifier units, simple crowave crystal-mixer circuits, special- ction mixers—for instance for beacon use, balanced mixers, local oscillator noise, and frequency control of local oscillators; there is also a chapter on special measurement techniques.

Particularly noteworthy is the treatment of the linear-network-theory representation of the crystal converter. This eliminates much of the cut-and-try approach in the design of a mixer and clearly shows the interdependence of the signal input circuit, local oscillator, mixer image impedance, and i-f input impedance.

Techniques and methods are described for the design of a mixer in the frequency range of 3000 to 25,000 megacycles, whether this be for a representative crystal or one to obtain the lowest possible noise figure. Beginners as well as the most advanced development engineers should find this volume most enlightening and a handy guide.

N. T. Lavoo

Computing Mechanisms and Linkages

(Vol. 27 of the M.I.T. Radiation Laboratory Series.)

Antonín Svoboda—McGraw-Hill Book Co., Inc., New York. 1948. 372 pp. $4.50.

This book is the first on its subject. Heretofore there has been no presentation of a means of synthesizing linkage function generators or linkage cams. The book is clear and explicit and contains many examples; the concepts are plainly stated and developed logically and clearly.

Linkage function generators or linkage cams are a combination of links, cranks, and slides arranged so that the displacement of the output element is a specified function of the displacement of the input element. Some commonly used linkage function generators are the Whitworth quick-return linkage and the sine-generator linkage. Mr. Svoboda briefly describes these mechanisms and then goes on to the treatment of more general linkage function generators.

The most easily designed of these is the crank, slide, and connecting-link combination. The book contains tables which give the parameters for a linkage which will generate an approximation to a desired function. An analytical method is then given for improving the approximation.

The next type of linkage function generator described is the three-bar linkage, which consists of an input crank, an output crank, and a connecting link. A nomograph is given which can be used to design this type of linkage. There is also a geometrical method for the design of these linkages.

The most difficult type to design is the linkage which generates a function of two variables. Two special cases are the multiplier and the divider. The method of design is based on the transformation of an ideal grid structure to a grid structure which can be approximated by a linkage.

Most functions can be generated with errors of from 1/100 to 1/1000 of the total motion with linkages designed by the methods presented. The linkages can be used individually or in combination.

A. G. Robbins
E. H. Cabaniss

Paramagnetic Relaxation

C. J. Gorter—Elsevier Publishing Co., Inc., New York. 1947. 135 pp. $2.25.

About one hundred technical papers have appeared in the rather specialized field of paramagnetic relaxation. The present book reviews the theory and experimental methods contained in these papers, and summarizes the important experimental results. The book is in reality a technical review, chiefly of interest to specialists; it combines an excellent literature survey of the subject with a summary of the present state of knowledge in the field.

John C. Fisher

Specify... D'ARSONVAL PORTABLE GALVANOMETERS AND MOVEMENTS...

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GM LABORATORIES · INC.

4318 N. Knox Ave. • Chicago 41, Ill.

Techniques in Experimental Electronics

C. H. Bachman—John Wiley & Sons, Inc., New York. 1948. 260 pp. $3.50.

A student or, in fact, anyone else watching a lecture demonstration in physics is not aware of all the "know-how" that has gone into the building and manipulation of the apparatus used by the lecturer to provide the desired result surely, accurately, and in a minimum of time. If the same student later goes into an industrial laboratory or takes up graduate work involving experimental work, he soon appreciates the great value of this know-how. This is particularly true in the field of electronics, which has attracted the attention of many thousands of laboratory workers in the past few years. Until recently, much of this practical knowledge has been the property of skilled glass-blowers and other technicians, acquired by years of experience handed down by older workers on a sort of old-time "crafts" basis.

This book contains a wealth of know-how in the highly specialized field of high-vacuum electronics. To a graduate in physics, it has the added feature of the true why and wherefore back of some of the techniques, something seldom acquired by the old method of learning.

The chosen field is covered thoroughly. By personal observation of the work of the author, this reviewer knows that not only does Dr. Bachman himself have exceptional talent in laboratory technique, but he also has the faculty for imparting it to others. It should go on the desk of every young electronics laboratory worker among his favorite handbooks.

W. C. White

The Radio Amateur's Handbook (25th Edition)

By the Headquarters Staff of the American Radio Relay League—American Radio Relay League, Inc., West Hartford, Conn. 1948. 760 pp. $2.00.

The quarter-century edition of the Radio Amateur's Handbook is, like the others, full of a wide variety of information on an interesting and sometimes useful hobby.

The general plan of the Handbook is attractive to the eye and gives the impression that it is easy to find what is wanted in it. This impression is readily confirmed. However, the shiny paper causes eye fatigue and makes one appreciate the obviously less expensive paper of the 1945 edition.

The articles on construction of receivers, transmitters, and measuring equipment are well illustrated with photographs and well documented with constructional and operational details, so that even a beginner can easily construct good equipment if only he starts with the simple ones and works up to the more complex.

Chapter 15, on uhf and microwaves, is interesting although unfortunate in the choice of illustrations of "evolution" in the Microwave section.

If all amateurs operated in accordance with the suggestions in Chapter 20, all bands would undoubtedly clear considerably.

Most of the data are reasonably accurate, but the Table of Dielectric Characteristics is not. For example, clear India mica has a power factor less than 0.01 per cent instead of the 2 per cent indicated, and clear fused quartz has a power factor of 0.001 per cent at 60 cycles and 0.02 per cent from 1 mc up to 10,000 mc instead of the figures given.

The vacuum tube data are as complete and as accurate as one could desire.

It is obvious that the catalog section has been edited. All the advertising is of the highest type, giving data to permit an intelligent choice of equipment.

H. R. Meahl

American Wool Handbook (Second Editio

Werner von Bergen and Herbert R. Maue
berger—Textile Book Publishers, Inc., N
York. 1948. 1155 pp. $8.00 in U.S. a
Canada, $9.00 in other countries.

The American Wool Handbook is a co
prehensive coverage of the American wool
and worsted industry, including copio
historical sketches; sources, characteristi
and properties of raw material; also exte
sive descriptions of preparatory, weavi
and finishing processes and machine
Considerable space is devoted to the ava
ability of wool fibers and to substitutes a
blends, taking due account of forei
influences, international trading, and su
plies of raw material. The importance
chemical and physical properties a
characteristics of all fibers are also cover

The text is interspersed with ma
tabulations, diagrams, and photogra
which add greatly to its clarity and va
for reference. Particularly is this true in t
consideration of machinery and manufact
ing processes.

Basic processes are described fully a
these are supplemented with extracts
latest developmental experience, especia
regarding weaving, dyeing, and finishi
where manufacturing techniques as well
science play such important roles.

Carpets and rugs represent a spec
branch of the industry, from the standpo
of both materials and manufacture, he
are treated in a separate chapter. Likew
felt, nonwoven and woven, is given separ
consideration.

The subject of physical and chemi
testing—methods, procedures, and analy
—is treated in considerable detail and,
course, a bibliography is included.

A. P. Mansfie

Vacuum-tube Circuits

Lawrence Baker Arguimbeau—John Wile
Sons, Inc., New York. 1948. 676 pp. $6.00

One of the reasons why university und
graduate teaching in the field of communi
tions has frequently avoided the practi
applications of vacuum tubes and th
associated circuits has been the lack of su
able textbooks geared to the assimilati
capability of the student. This textbo
might well serve as a portion of the foun
tion for such a course.

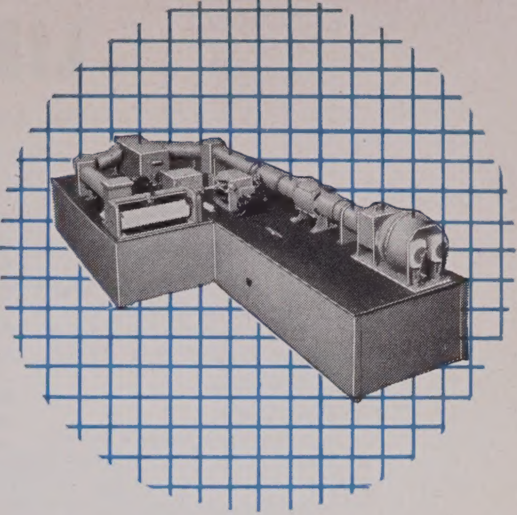
Intentionally, the subjects selected
discussion were taken from those of curr
interest. Diodes, triodes, pentodes, mag
trons, and klystrons are considered in c
junction with circuits as they apply to re
fiers, Class A, B, and C amplifiers, mo
lators, oscillators, detectors, mixers, limit
etc. In each case, an attempt is made
direct the emphasis to the physical conce
involved; however, the associated circu
and their behavior serve to elucidate id
of general importance.

The many examples throughout the bo
which demonstrate the general methods
engineering solution, together with the
merous problems given, clarify the part
ular topics and establish more firmly
principles involved. Topically, the ba
concepts underlying frequency modulati
amplitude modulation, and inverse feedba
are covered satisfactorily. Television a
microwaves, as broad subjects, inevita
receive only a nominal amount of consid
ation. However, the transient response
the simpler video amplifier coupling circu
together with principles of compensation,
treated adequately.

A knowledge of alternating-current c
cuits, of calculus, of a minimum of diff
ential equations, and of Fourier series
the important prerequisites for a study
this textbook.

L. M. Lee

COLOR . . . Spectrophotometer pays for itself in one project

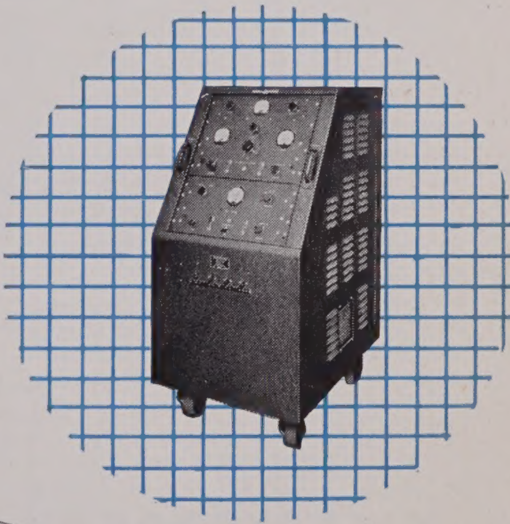


Ten years ago, the Harshaw Chemical Company developed a new opacifier, called Uverite, to replace tin oxide. A G-E recording spectrophotometer more than paid for itself on this first project. But the important news is this: Harshaw's chemists say it has been paying for itself repeatedly since then by giving quick results and a permanent record for color analysis, comparison, etc.

Many other users are finding this high-precision laboratory instrument valuable for such jobs as matching colors, mixing pigments, making color analysis, measuring gloss, standardizing colors, preparing color specifications, etc. It has been adopted by the American Standards Association as the basic color-measuring instrument. Write for GEA-3680.

VACUUMS and PRESSURES...

Leak detector pays for itself the first month



For testing high-frequency vacuum tubes for leaks, a well-known laboratory installed a G-E leak detector. Previous methods were slow, inconsistent, and inaccurate.

The leak detector proved itself quickly. It made it possible to find leaks many times smaller and much faster, recheck suspected leaks quickly, and assured vacuum tightness of the tubes.

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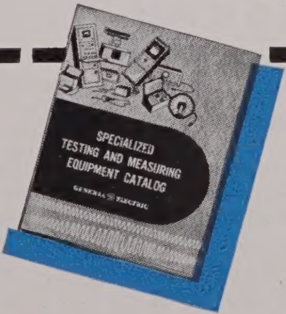

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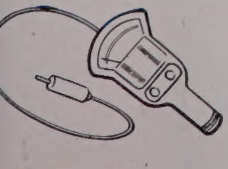

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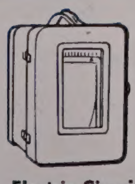

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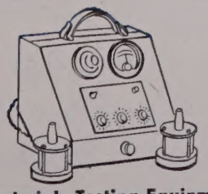

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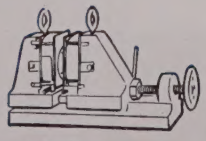

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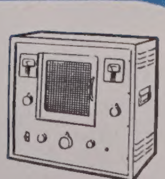

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J. A. Hutcheson—*Steel*, Mar. 1, 1948; v. 122, pp. 88-89.

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H. O. Smith—*Factory Man. & Maint.*, Mar., 1948; v. 106, pp. 105-115.

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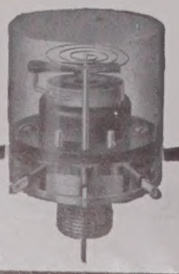

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Findings of a section of the Dept. of Scientific and Industrial Research, England.

ELECTRIC HEATING, DIELECTRIC

High-frequency Molding Method Applied to Compound Curvatures in Wood.

P. H. Bilhuber—*Mech. Engng.*, Mar., 1948; v. 70, pp. 213-216.

The "Raytronic" method for dielectric molding of laminated wood products.

FAULTS, ELECTRIC

Fault Currents Estimated from Curves.

J. N. Banky—*Elec. Wld.*, Mar. 13, 1948; v. 129, pp. 108-109.

Curves plotted from calculating-board study can be applied to any particular grid or network with fault current at one point used as base.

GEARS

Graphical Determination of Gear Contact Ratios.

D. W. Dudley—*Prod. Engng.*, Mar., 1948; v. 19, pp. 152-155.

Contact ratios, form diameters, hob undercut diameters, and other gear-action problems can be solved quickly and accurately with one type of curve chart.

HYDRAULIC TRANSMISSION

Hydraulic Circuit Analysis.

H. M. Reese—*Mach. Design*, Mar., 1948; v. 20, pp. 149-152.

Shows the importance of considering impulse pressures when designing hydraulic power systems.

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Mechanical Activation—A Newly Developed Chemical Process.

M. C. Shaw—*Jour. App. Mech.*, Mar., 1948; v. 15, pp. 37-44.

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Process Design.

Chem Engng. Prog., Mar., 1948; v. 44, pp. 253-260.

The first installment of a two-part symposium.

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Improved Method for Mounting Bearings and Cou plings.

A. S. Murray—*Iron & St. Engr.*, Mar 1948; v. 25, pp. 61-65.

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D. Q. Posin—*Phys. Rev.*, Mar. 1, 194 v. 73, pp. 496-509

Investigation of the breakdown fiel strength of air, under various conditions, a wavelengths of 1.25, 3, and 10 centimeter

STANDARDS—STEAM TURBINES

Standardization of Industrial Steam Turbines Is Comin

L. E. Newman—*Power*, Mar., 1948; v. 9 pp. 143-145, 190a.

By following a simplified design patter for new generating stations a start can b made, even though standardization of i dustrial-type turbine-generator units is n yet possible.

STEEL

Practical Heat-treatment of High-speed Steel Cuttin Tools.

W. E. Bancroft and W. M. Wight—*Met Prog.*, Apr., 1948; v. 53, pp. 545-555.

How to improve heat-treatments of hig speed steel—both the older types and th newer ones containing molybdenum.

STRAINS AND STRESSES

Development of Residual Stresses in Strip Rolling.

R. McC. Baker and others—*Metals Tech* Apr., 1948; v. 15, Tech. Pub. No. 2333.

The effect of roll diameter, strip thicknes reduction per pass, metal, or metal tempe on the magnitude of residual stresses d veloped in nonferrous strip.

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Maintenance of Outdoor Lighting Equipment.

Francis T. Tillemans—*Illum. Engng.*, Apr 1948; v. 43, pp. 377-394.

A study of the decrease in illuminatio output of street-lighting and floodlightin installations as the result of dirty equi ment. Effects of cleaning.

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Planned Tooling Whittles Costs.

Harry S. Wharen—*Am. Mach.*, Mar. 1 1948; v. 92, pp. 140-143.

Smart planning on tooling of engin mounts, project supervision, and skille workers mean close tolerances on comple parts.

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Visibility of Distant Objects.

Seibert Q. Duntley—*Optical Soc. of A Jour.*, Mar., 1948; v. 38, pp. 237-249.

Identifies the principal factors involve in the visibility of an object, indicates ho each factor affects the range of visibilit and supplies charts which, by combinin these factors, enable the limiting range t be found under any set of prevailing cond tions.